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General Sir ARTHUR THOMAS COTTON, K.C.S.I.

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MINISTRY OF CULTURE · GOVERNMENT OF INDIA

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THE ENGINEERING WORKS OF THE GÓDÁVARI DELTA:

A DESCRIPTIVE AND HISTORICAL ACCOUNT.

COMPILED FOR THE MADRAS GOVERNMENT

BY

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IN TWO VOLUMES.

VOLUME I.

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PREFACE.

IMPERIAL RECORD DEPARTMENT

In preparing the following monograph on the great Engineering Works of the Gódávari Delta, with which I was connected from 1872 to 1893 either on actual construction as an Executive Engineer, or in general supervision and direction as Superintending Engineer and then as Chief Engineer for Irrigation, I have condensed to the utmost the narrative of operations subsequent to 1852; but in dealing with the most interesting period before that year, I have considered that the story should be told more fully, and as far as possible in the words of Sir Arthur Cotton and of those associated with him in the inception of the scheme and the construction of the great Anicut and its Head Works. This has been done by means of copious extracts from their reports and letters, many of which will be found printed in full in Volume III of the "Professional Papers of the Madras Engineers."

Unforeseen delays in the preparation of some of the illustrations and plans for this work have retarded its publication.

GEORGE T. WALCH.

ECKFORD, OOTACAMUND,
February 1896.

CONTENTS.

CHAPTER I.

THE GÓDÁVARI RIVER AND DELTA.

PAGES

Course and discharge of River—Its affluents—Its Gorge—Branches—Season for floods—Height of floods at Anicut—Drift brought down the river—Sacredness—Boundaries of District—The Delta—Eastern, Central, and Western, Sections—Coringa and Cocanada—Madapollam and Narsapur—Sketch Map 1-6

CHAPTER II.

THE GÓDÁVARI ANICUT—PROPOSALS AND SANCTION.

First suggestion for an anicut, by Mr. Topping—Famine in district 1832-33, and following bad seasons—Sir Henry Montgomery sent to report—His report—Captain Arthur Cotton's first report—His second report with definite proposals and general estimate—Recommendation of Government of Madras—Despatch of Court of Directors sanctioning 7-27

CHAPTER III.

THE GÓDÁVARI ANICUT—SITE AND DESIGN.

Site—Design for; original, modified, and final—Consideration of final design—Necessity for extensive protection below the work—The Anicut, and the Head Works in connection with it 28-33

CHAPTER IV.

GÓDÁVARI ANICUT AND HEAD WORKS—EXECUTION FROM COMMENCEMENT TO END OF 1851-52.

Major Arthur Cotton's report of work done to August 1847—Sanguine expectations for 1848—Major Cotton's report of progress to June 1848 and first supplemental estimate—Damage to Works by fresh of June—Major Cotton goes on leave and Captain Orr assumes Charge—Captain Orr's reports of 15th August and 2nd October 1848—Second supplemental estimate, 16th September 1848—Despatch of Court of Directors about first supplemental estimate—Committee appointed to report on the Works—Extracts from its report—Captain Orr's report of progress, 15th May 1849—His report of damage caused by floods of May—Captain Orr's reports, 1st and 16th June—Damage caused by floods of 6th and 16th September—Action of groynes—Mr. Forbes' letter giving state of progress early in 1850—Damage done by fresh of June 1850—Colonel A. Cotton resumes charge of the Works—His report, 12th December—Proposed lengthening of Vizéswaram branch—Working season, 1851—Virtual completion of Anicut and Head Works, 31st March 1852—Colonel A. Cotton's report on—Order of Government—V. Veeranah Garu—Colonel A. Cotton becomes Chief Engineer of the Madras Presidency—Major F. C. Cotton assumes charge of the Gódávari Works 34-62

CHAPTER V.

ALTERATIONS IN THE ANICUT AND HEAD WORKS AFTER THEIR CONSTRUCTION.

PAGES

The Anicut—Serious accident in 1857—Failure of some of the works and their renewal—Vizéswaram Head Lock and Head Sluices—Central Delta Head Sluices—Eastern Delta Head Lock—Central Delta Head Lock—Eastern Delta Head Sluices, improved means of regulation—The three sets of Under Sluices, additions and improved shutters and gearing 63-71

CHAPTER VI.

THE GUNNARAM AQUEDUCT.

Colonel A. Cotton's proposals and estimate—Colonel Baird-Smith's description and remarks—Rapidity of construction—Excess of cost—Lieutenant Haig's memorandum—Colonel A. Cotton's report—Damage caused by floods of 1853 and 1854—Estimates for repairs and strengthening—Alterations under 'Completion Estimates'—Accident in August 1884—Work entirely submerged by flood of October 1891—Extra front flooring constructed, 1888-91 72-84

CHAPTER VII.

WORKS IN THE DELTA—SANCTIONS—EXECUTION—COST.

Sanctions before Colonel A. Cotton left the district—Friction between Colonel Cotton and Government—His letter to Government, 11th November 1852—State of progress of means of utilizing anicut water in 1853—Report on by Colonel A. Cotton—Sanctions between 1853 and 1869—Introduction of system of 'Loan Funds'—'Completion Estimates' for Eastern and Western Deltas sanctioned in 1871—'Completion Estimates' for Central Delta and revised estimates for Eastern and Western Deltas sanctioned in 1882—Secretary of State's Despatch sanctioning—Comparison between Original and Revised Estimates—Abstract Water-distribution Statement—Closure of Construction Estimates, 1890—Report on, April 1891—Despatch from Government of India to Secretary of State—Despatch of Secretary of State—Statement of outlay to end, 1889-90—Subsequent Expenditure—Total Expenditure to end, 1893-94, both 'Capital' and 'Revenue' 85-116

CHAPTER VIII.

GENERAL DESCRIPTION OF WHOLE SYSTEM OF CANALS, ETC.

The Anicut—Datum of levels of the system—Importance of the Embankments between the branches of the Anicut—Head-works in connection with the Anicut—Canals, Drainage, etc., of Eastern, Central and Western Deltas 117-130

CHAPTER IX.

MATERIALS, DESIGNS, ETC., OF WORKS.

Earthwork—Objections to use of Drainages for other purposes—Old Native Channels used for distributaries—Colonel Baird-Smith's remarks on—Formula used—Brickwork—Concrete—Súrki mortar—Stone used—Locks—Lock-gates—Weirs—Aqueducts—Irrigation Sluices—Bridges 131-135

CSL

CHAPTER X.

IRRIGATION.

PAGES

The primary object of the Canals—Areas of Irrigation originally anticipated—Growth of Irrigation—Actual area in 1893-94—Consideration of possible considerable increase—Areas available—Water available—Duty of water—Economy in use of water—Storage Reservoirs—Rice cultivation—Other crops—Irrigation Rules and Rates—Increase of rates in 1895—Length of Distributaries—Rainfall 136-142

CHAPTER XI.

NAVIGATION.

Combination of Irrigation and Navigation—Opposition to—Colonel A. Cotton's insistence in favour of—Success of, in the Gódávari Delta—Attempt to show financial results of Navigation separately, inadvisable—Occasional difficulties in combining the two purposes—Memorandum about—Development of Canal traffic—Direct returns from Navigation—Licenses and Tolls, past, present, and intended—Maintenance Charges against Navigation—Navigation rules—Towage of boats—Sailing—Steam-power on Canals 143-152

CHAPTER XII.

RESULTS OF THE GÓDÁVARI DELTA WORKS.

Direct money returns—Growth of Revenue of the District—Imports and Exports—Population—Cultivation—Communications—General 153-157

APPENDICES.

I. Expenditure on Capital Account 158-161
II. Population of Gódávari District 162

INDEX 163-165

GSL

LIST OF ILLUSTRATIONS, VOLUME I.

		PAGE
Portrait of Sir Arthur Cotton	*Frontispiece.*	
View of the Gódávari Gorge near upper end	To face page	2
View of the Gódávari Gorge near lower end	" " "	4
Sketch Map of the Gódávari Delta	" " "	6
Proposed Sections of Anicut	" " "	29
Sections of Anicut as completed	" " "	31
Sketch showing arrangements for Works in 1848-49	" " "	42
Sketch showing effect of River Current in 1849	" " "	49
Sketch showing Method of closing breach	" " "	51
View of Dowlaishweram branch of Anicut from the Under-sluices ...	" " "	63
View of Central Delta Head Sluices	" " "	69
View of Gunnaram Aqueduct from upper end	" " "	72
View of Gunnaram Aqueduct, down stream face	" " "	83
View of Gunnaram Aqueduct with flood going over it in October 1891 ...	" " "	84
Skeleton Map showing Channels, &c., in 1853	" " "	91
View of Maddúr branch of Anicut	" " "	117
View of head of Main Canal, Eastern Delta	" " "	118
View of Mukkamala Lock	" " "	133

LIST OF PLANS, VOLUME II ('ATLAS VOLUME').

No.		Referred to in Vol. I, pages
1.	**Diagram** of heights of the Gódávari River from 1st July to 15th October in certain years	2
2.	**Chart** showing positions of Anicut and Head Works	28, 117
3.	**Cross Sections** of the Anicut	31, 32
4.	**Arrangement** of works on left flank of the Dowlaishweram Anicut, as originally built	69, 71
5.	**Condensed Sections** of principal Canals—Eastern Delta—2 sheets...	121
6.	Do. do. Central Delta—1 sheet ...	124
7.	Do. do. Western Delta—3 sheets..	128
8.	**Under-sluices** at Dowlaishweram	71, 118
9.	Do. do. ; shutters and gearing	71
10.	**Shutters and gearing** of Under-sluice at Vizéswaram	71, 118
11.	**Head Sluices,** Eastern Delta; Dowlaishweram	71, 118
12.	Do. Western Delta; Vizéswaram	67, 118, 125
13.	Do. Central Delta; Bobberlanka	69, 118, 122
14.	Do. do. do. ; shutters and gearing ...	69, 71, 118
15.	**Head Lock,** Eastern Delta; Dowlaishweram	70, 118, 133
16.	Do. do. do. upper and intermediate gates	70

CSL

No. Referred to in Vol. I, pages

17. **Head Lock,** Central Delta; Bobberlanka 71, 118, 122, 133
18. Do. (Old) Western Delta; Vizéswaram 66, 118, 133
19. **Canal Lock,** Ralli—Gunnaram Canal, C.D. 133
20. Do. (Concrete) Gopálpuram—Gunnaram Canal, C.D. ... 133
21. Do. do. do. Tumble gates. 133
22. Do. Sidhantam—Bank Canal, W.D. 133
23. Do. Palakolu—Narsapur Canal, W.D. 133
24. Do. (Tidal) Mogultur—Narsapur Canal, W.D. 127, 133
25. Do. Gumampád—Attili Canal, W.D. 133
26. Do. (Double) Mudhapuram—Junction Canal, W.D. 128, 133
27. Do. Chinnakaparam—Venkiah and Weyéru Canal, W.D. ... 128, 133
28. **Lock Weir**—Samalkót, E.D. 134
29. Do. Lolla, C.D. 134
30. Do. Paravali, W.D. 134
31. Do. Palakolu, W.D. 134
32. Do. Mamudúr, W.D. 134
33. Do. Godicherla, W.D. 134
34. **Surplus Weir**—Bellampúdi, C.D. 134
35. Do. Nundamúr, W.D. 125, 134
36. **Aqueduct** Gunnaram, C.D. 73, 134
37. Do. 20th mile Ellore Canal, W.D. 134
38. **Irrigation Sluice**—Sidhantam Parallel Channel, W.D. 134
39. Do. Undrájavaram Channel, W.D. 134
40. Do. Ralinghi Channel, W.D. 134
41. Do. Mid-level Channel, W.D. 128, 134
42. Do. Komara Channel, W.D. 134
43. **Outfall Sluice** to Nakkala Drain, W.D. 129
44. **Sketch Map**—Eastern Section of the Delta 117
45. Do. Central do. 117
46. Do. Western do. 117

ENGINEERING HISTORY

OF

THE GÓDÁVARI DELTA.

CHAPTER I.

THE GÓDÁVARI RIVER AND DELTA.

THE Gódávari takes rank amongst the great rivers of India next after the Ganges and the Indus. Rising some 70 miles north-east of Bombay and only 50 miles from the Arabian Sea, it runs in a generally south-east direction across the Peninsula till, after a course of nearly 900 miles, it falls into the Bay of Bengal about 250 miles north of Madras. It receives the drainage from 115,000 square miles, an area greater than that of England and Scotland combined, and its maximum discharge is calculated to be 1½ millions of cubic feet per second, more than 200 times that of the Thames at Staines, and about three times that of the Nile at Cairo.

Its chief affluents are, the *Manjira* from the Nizam's Dominions; the *Pranhita* which is itself formed by the confluence of the three great rivers of the Central Provinces, viz., the Wardha, the Paingange, and the Waingange; the *Indravati;* and the *Sabari* (or Severi).

Shortly after receiving the last-named river the Gódávari begins to wind amongst the spurs of the Eastern Ghâts, which gradually close in on it, till it has to force its way through a gorge which for two miles is so narrow that along the greater part of the distance a stone may be thrown from either bank to the middle of the stream. The hills here rise to a height of between 2,000 and 3,000 feet with steep, though not precipitous, sides, and are clothed from water's edge to summit with luxuriant tropical vegetation.

Through this beautiful gorge the river in its low stages glides with but little disturbance, and is easily navigated even by small boats, but during floods it foams past its obstructions with a velocity and turbulence which no craft that ever floated could stem. So great is the action of the stream at such times that the rocky bed has been scoured out to depths popularly supposed to be unfathomable, but which, as the writer has himself ascertained, do really vary from 100 to nearly 200 feet. High floods rise quite 50 feet at the place, so that in the defile there is then a torrent from 150 to 250 feet in depth. For 20 miles beyond the gorge the river winds in a succession of lake-like reaches amongst the eastern spurs of the hills, till near the village of Polavaram it emerges into the plains of the Eastern or

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Coromandel' Coast. Small outlying hills however occur along its left bank for some 25 miles further; the last of these which lies close to the river is at Dowlaishweram, where the Gódávari has attained a width of nearly 4 miles. It then divides into two branches and its delta begins.

The branches bear the names of two of the seven '*Rishies*,' or sages, who according to Hindu mythology escaped the deluge, the northern branch being known as the '*Gautami* Gódávari,' the southern one as the '*Vasishta*,' or 'Vasista,' Gódávari. The Gautami branch after an easterly course of 45 miles, during which it throws off two minor branches known as the 'Vriddha' * Gautami and the 'Coringa river,' respectively, reaches the sea nearly due east of Coringa in latitude 16° 45′ N.; whilst the Vasishta branch, trending away more to the south, has its mouth in latitude 16° 20′ N.; its length is about 50 miles, and at about half way along its course it parts with a considerable portion of its flood waters by a branch from its left side known as the 'Vainateyam' Gódávari.

The greater portion of the area drained by the Gódávari receives much more rain in the south-west than in the north-east monsoon, and it is during the former therefore that the river brings down most water. It begins to rise at Dowlaishweram some ten days after the south-west rains set in at Bombay, usually about the middle of June, and it is almost always high till October. The season for floods is then over, but during the next two months, or so, there are occasional freshets caused by the north-east monsoon rains over that part of the catchment basin which comes under their influence. When the north-east rains have ceased, the river gets lower and lower, falling to below the crest of the anicut some time in March, and arriving at its lowest stage about the end of May, when its discharge is at times as little as 1,500 cubic feet per second. The 'diagram,' which will be found in the Atlas Volume, shows graphically the rises and falls of the river between 1st June and 15th October for a few average years, for some of exceptionally high floods, and for others of exceptionally small discharge. In it are shown the two highest floods known, that of 21st August 1886 and that of 3rd October 1891. In the latter, it will be seen, the flood attained a height of 17 feet above the crest of the Dowlaishweram branch of the anicut; it was somewhat higher on the other branches.

In its moderate freshes the river brings down but little drift; when however it swells into a really high flood, its broad surface is plentifully strewn with floating débris of all kinds; giants of the forest which have toppled into the stream, whose roots and branches rise and fall with weird effect as they are rolled over and over in the stream; bambus interlaced in wild confusion; jungle grasses and river rushes in tangled masses like floating islands; and not infrequently carcasses of animals swept from the 'lankas,' or islands, which the flood has deeply submerged or entirely washed away. Most of this wrack passes over the anicut harmlessly enough, merely breaking now and then a few of the cast-iron posts on its crest, but some of it is driven by the prevailing winds into the corner or 'pocket,' at the left flank of the anicut, where stand the Dowlaishweram head lock and sluices, and is a source of much trouble.

The Gódávari is one of the twelve holy rivers of India. From Trimbak where its first trickle issues through the mouth of a sacred idol, to where

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* 'Vriddha,' Sanscrit = ancient.

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Photographed by W. Jopp, Esq.

Photo.-Print Survey Office, Madras, 1895.

GORGE OF THE GODAVARI LOOKING UP STREAM FROM NEAR UPPER END

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it carries into the Bay of Bengal the waters gathered from upwards of a hundred thousand square miles, there are many temples and shrines along its banks, to which pilgrims come from all parts of India to bathe and be purged of their iniquities. This is especially the case once in every twelve years when its waters are believed to be in communication with those of the Ganges by some mysterious underground channel.

Gódávari District.

The District which now bears the name of the great river that flows through it was, till 1859, known as the 'Rajahmundry' district. It is one of the five *Northern Circars* of the Madras Presidency, acquired from the Nizam towards the end of last century.

"* It is divided into nearly equal parts by the river Gódávari. It lies between 16° 18′ and 17° 56′ 35″ N. latitude, and 80° 56′ and 82° 40′ E. longitude. It is bounded on the north by the territory of His Highness the Nizam and the Central Provinces; on the north-east by the district of Vizagapatam; on the east and south by the Bay of Bengal; and on the west by the Kistna district."

Its area is approximately 8,000 square miles; about one-quarter of which is known as the 'Gódávari delta.'

Gódávari Delta.

The 'Delta' proper lies, of course, between the two branches of the river, but it has been customary to also include under the general name of the 'Gódávari Delta' the alluvial tracts deposited by the river which stretch along the left bank of the Gautami branch and the right bank of the Vasishta branch; this inaccuracy is so unimportant and so convenient that it may well be adhered to.

The 'Delta,' using the word in the extended application just stated, has an area of about 2,000 square miles; the river divides it into three parts; one on the left side of the Gautami branch; one embraced by the two branches of the river; and one on the right side of the Vasishta branch. These have, in connection with the engineering works for their irrigation and navigation, been generally distinguished as the *Eastern*, *Central*, and *Western* Sections of the delta, or simply as the *Eastern Delta*, *Central Delta*, and *Western Delta* respectively.

Eastern Section of the Delta.

The first of these, lying between the Gautami Gódávari and the high ground which follows a line somewhat north of east from Dowlaishweram to Samulcottah (or Samalkót), has an area of about 450 square miles, including Coringa island. That island is separated from the main land by a minor branch of the Gódávari known as the 'Coringa river,' a tidal channel which, leaving the main river at the French territory of 'Yanam' (or 'Yanaon'), runs nearly due north to Cocanada bay. Parts of this branch, which is now one of the smaller mouths of the Gódávari, were opened out less than fifty years ago with the objects of facilitating navigation and of improving the drainage of this section of the delta. Coringa lies along the northern end of this river, or tidal creek, at the south-west corner of the bay formed by the land pushed out into the sea by the northern mouth of the Gautami Gódávari. It used to be the most important port in the 800 miles between Madras and the Hugli, and was visited by vessels which in those days were considered to be of large tonnage. The approaches to Coringa were shoaling up even before the work above referred to was carried out, but the greater quantity of silt

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* *Gódávari District Manual.* H. Morris, 1878.

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brought into the 'pocket' of the bay by the increased discharge from the Gódávari when in flood, doubtless somewhat hastened on the deterioration of the port, till there lay between it and the open sea a mud flat of many miles wide, the tidal channels through which could not float any vessels but those of light draught. Coringa has, therefore, ceased to be a port of any value, and is resorted to only by native coasting craft for the purposes of repair. Its place has been taken by Cocanada, 10 miles further north, which, though but comparatively a few years ago of so little consequence that to this day it is not named on many maps of India, is now the third in importance of all the ports of the Madras Presidency, judging by the value of its imports and exports, which exceed 190 lakhs of rupees annually*. It is to the facilities afforded by this port for the export of surplus produce and for the extensive imports demanded by a prosperous people that the astonishingly rapid development of irrigation and of canal navigation in both the Gódávari and Kistna districts is largely due.

For the drainage of the greater part of this Eastern Section of the delta, nature provided, and provided imperfectly, by a channel known as the 'Thooliabaghá,' or 'Tuliabágá,' which will be found so often referred to that it requires special notice here. Commencing near the head of the delta it ended after a tortuous course in the tidal creek near Cocanada. Under native régime it had been utilized as an important source of irrigation by cutting a channel to it from the river. As, however, there was no regulating work to prevent immoderate quantities of river water from entering it, it not infrequently became surcharged during floods, and was then the cause of extensive damage to the adjacent country. Besides this channel there were in this section of the delta three other channels with open mouths from the river, known as the 'Sopilla,' 'Taykee' and 'Masakapilly,' which gave a precarious irrigation to small areas.

Central Section of the Delta.

The *Central Section*, or Delta proper, has an area of rather under 505 square miles (excluding Polavaram Island). From the Gautami Gódávari, which runs along its eastern and northern sides, a minor branch, known as the 'Vriddha Gautami' separates at about 30 miles from the head of the delta and forms an island known as the Polavaram† (or 'Poláram') island, which still remains unconnected with the anicut system of canals.

From the Vasishta Gódávari, which forms the western boundary of this Central Section, at about 25 miles from its head, a large branch is thrown off, known as the Vainateyam Gódávari which falls into the sea at Bendamur-lanka, where the East India Company, in its trading days, had one of its 'factories.' The island enclosed between this branch and the main stream is known as the Nagaram Island; it has an area of about 120 square miles, and is one of the most fertile parts of the whole delta. The aqueduct by which this island was connected with the system of irrigation and navigation from the anicut will be found to receive special notice in the following pages, its construction having been in many ways a remarkable feat.

The natural drainage of the main portion of this Central Section was by the 'Gorinkala' and 'Kausika,' or 'Kowsika,' drains, both of them

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* In 1893-94, imports Rs. 37,06,955, exports Rs. 1,54,59,084.

† Must not be confounded with the village of the same name, where the river leaves the hills, mentioned above.

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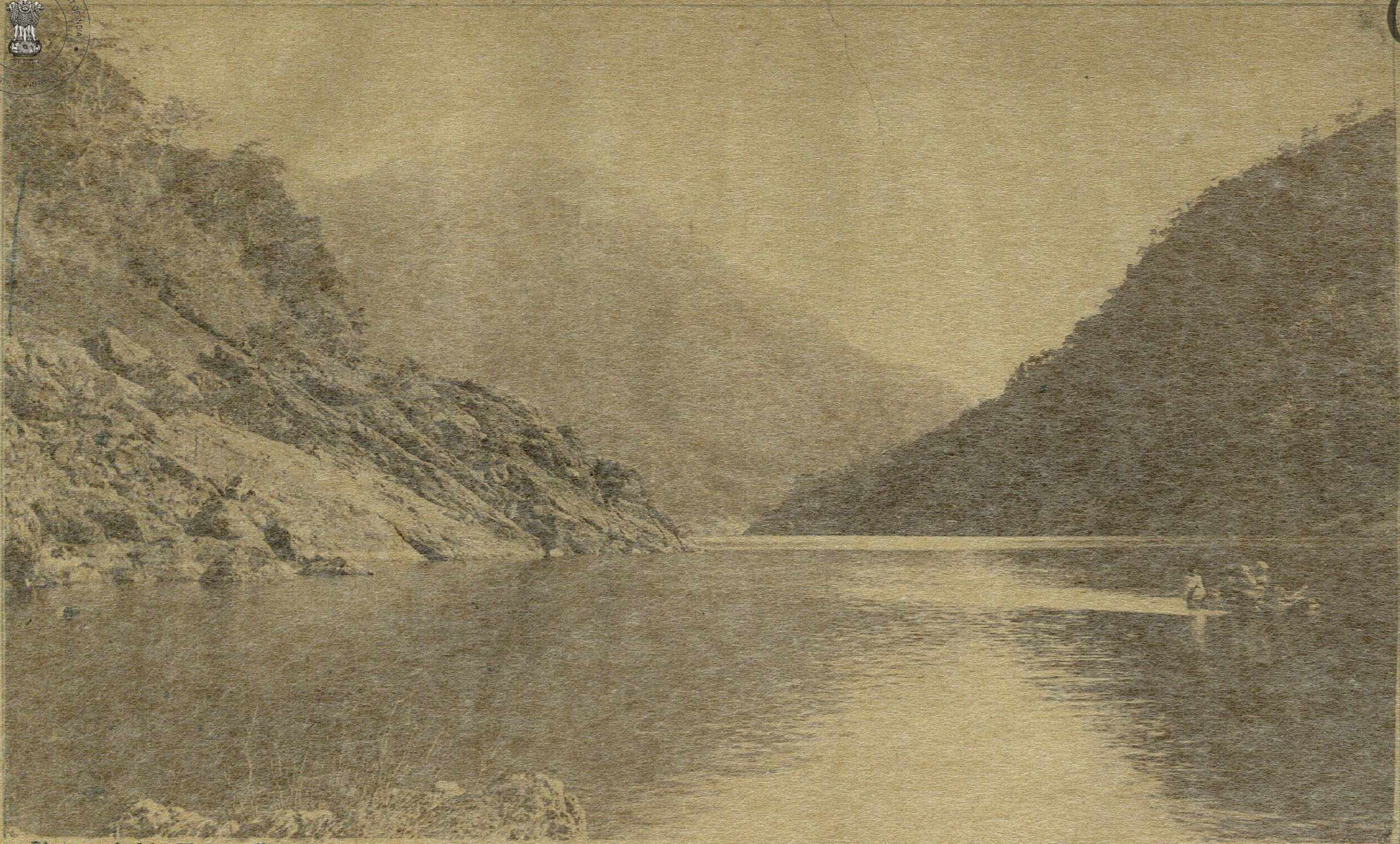

Photographed by W. Jopp, Esq.

Photo-Print Survey Office, Madras 1895.

Gorge of the Godavari looking Up Stream from near Lower End

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being spill channels from the Gódávari. They were used for some time after the construction of the anicut as rough and ready means of starting irrigation and navigation; the Gorinkala has now been restored to its legitimate use as a drainage channel pure and simple, but parts of the Kausika have been incorporated in a canal, and it is separated into two portions, the upper being joined to the Gorinkala near where that channel falls into the Vainateyam Gódávari, a short distance below the head of that branch. The Kausika originally traversed nearly the whole length of the delta and was in the old days considered to be one of the main branches of the river.

This *Central Section*, though on each side of it ran a magnificent river, was almost "* wholly destitute of the means of river irrigation, water being admitted on the land only during a very few days in the year, through small sluices constructed in the river bank."

Western Section of the Delta.

The *Western Section* of the Delta has an area of rather over 1,000 square miles, and is therefore about equal in size to the other two sections combined. It stretches westward from the Vasishta Gódávari for about 35 miles to where, at about the same distance from the Kistna, it meets the so-called 'Delta' of that river. Between the alluvial plains which owe their origin to the two great rivers, there remains a depression as yet unfilled by their deposits, which is known as the 'Colair' (or Koléru) Lake, occupying an area of 170 square miles, including its islands. Little silt-laden water from the Gódávari and the Kistna now reaches this lake, but upland streams, draining in all some 1,600 † square miles, fall into it. The surplus water of the lake finds its way to the sea by the 'Upputéru' (Salt river), a tidal stream, some 20 miles long, which issues from the south-east corner of the lake. This river and an arbitrary line through the lake itself form the boundary between the lower portions of the Gódávari and Kistna districts.

Of this Section of the Delta the following three streams were the natural main drainage lines, and they still remain so, though under conditions considerably altered from those which obtained before the system of canals from the anicut came into existence:—

First: The *Weyéru* (or 'Waiyeru'), known in the upper portions of its course before it enters the delta as the 'Yerra-Kalwa' (Yellow stream).—After a south-easterly course of some 50 miles, through a drainage basin of 850 square miles, this stream turns to the south-west at a point where it has approached to within 8 miles of the Gódávari, and it was there joined by a tributary called the Rállu-Madugu, which, having run for many miles close to the Gódávari, almost touches it at the head of the delta. Here the native cultivators in the old days made two cuts known as the 'Old' and 'New' Apparow channels, by which water could be taken from the Gódávari when sufficiently high. The means of irrigation thus secured for a considerable area of lands along the Weyéru was of course precarious, and not infrequently a source of danger, as there was no efficient arrangement for excluding river floods. The Weyéru ended in the Colair Lake, but on its way there threw off several branches, which meandered to the Upputéru through the swamps along its northern side.

Second: The *Góstanadi* (or 'Goshta-nuddy').—This was doubtless once a branch, or spill channel, of the Weyéru or of its tributary the Rállu-Madugu,

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* Captain Orr's letter No. 184, dated 3rd August 1849.

† Exclusive of what comes to the lake from the Yerra-Kalwa or Weyéru.

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and from near the junction of the two streams ran southwards to the Upputéru, joining that river a few miles from its mouth. An artificial channel from the Gódávari, some 8 miles below the head of the delta, used to bring water, when the river was sufficiently high, into the Góstanadi for irrigation. Like the other similar channels it was without any works to regulate the quantity of water entering it, and was therefore often a source of danger to the country it was intended to benefit.

Third : The *Nakkala.*—This was once a spill channel of the Gódávari, leaving it some 12 miles below the head of the delta and rejoining the river about the same distance above its mouth.

All these three main drainage channels of the Western Section were made use of to expedite the distribution of the water from the anicut directly it was brought into action, and parts of the Weyéru and Góstanadi have been permanently incorporated in artificial irrigation and navigation canals. The Nakkala however has, by recent arrangements, been relieved of all duty except its legitimate one of carrying off surplus water.

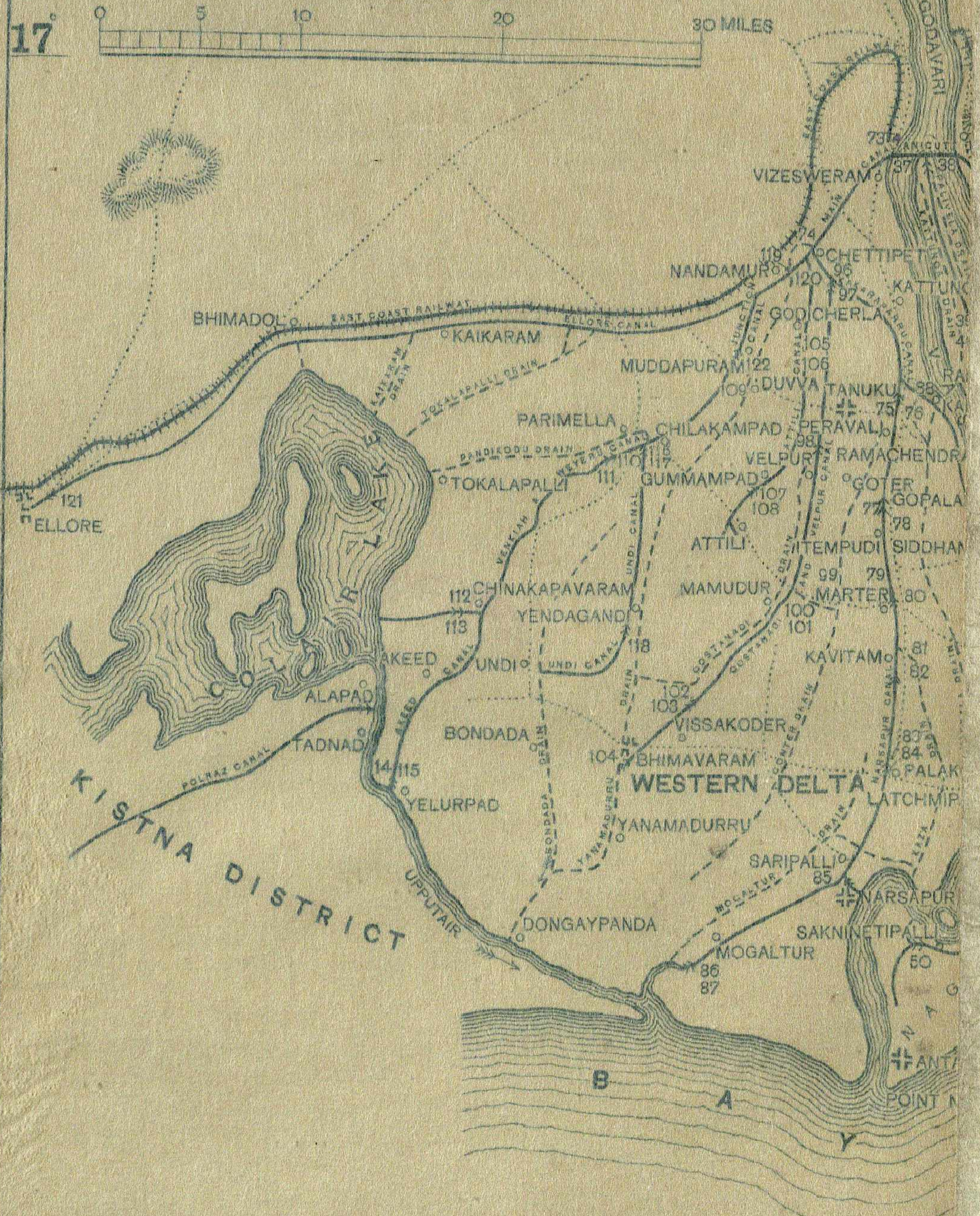
Besides the lands irrigated by way of the Weyéru and Góstanadi above noticed, a considerable area in this Section of the delta received an irregular and unregulated supply of water from the Gódávari by means of two channels—one known as the 'Bhoopiah' (or 'Bhúppaiya') with its offtake from the river at about 10 miles from the head of the delta, and the other called the 'Pamooloo' (or 'Pémulu') to which there were two or three open cuts lower down the river.

On the right bank of the Vasishta Gódávari, about 5 miles from its mouth, stands the native town of 'Madapollam,' where there was an important East India Company's 'factory.' It gave its name to a class of cotton goods still known in the market as *Madapollams.* When the sea-borne trade of the coast was carried on by small craft, now almost entirely run off by large steamers, the mouth of the Vasishta Gódávari was at certain times of the year a much frequented port, and owing to its convenience for shipping, a suburb of Madapollam called 'Narsapur' grew into an importance which quite overshadowed its parent town. Since, however, the Company's factory was done away with in 1829, and Cocanada has absorbed almost all the export and import of the whole district, Narsapur has ceased to be of commercial consequence, but it is still a large native town and gives its name to an important taluk, and to the 'point' at the mouth of the river, which to navigators is a well-known land mark warning them to give a wide berth to the shoals off the mouths of the Gódávari.

A reference to the accompanying sketch map will, it is hoped, make this condensed description of the Delta clear.

SKETCH MAP
OF THE
GODAVARI DELTA
SHOWING POSITIONS OF
THE PRINCIPAL IRRIGATION & NAVIGATION WORKS

SCALE 1 INCH = 8 MILES



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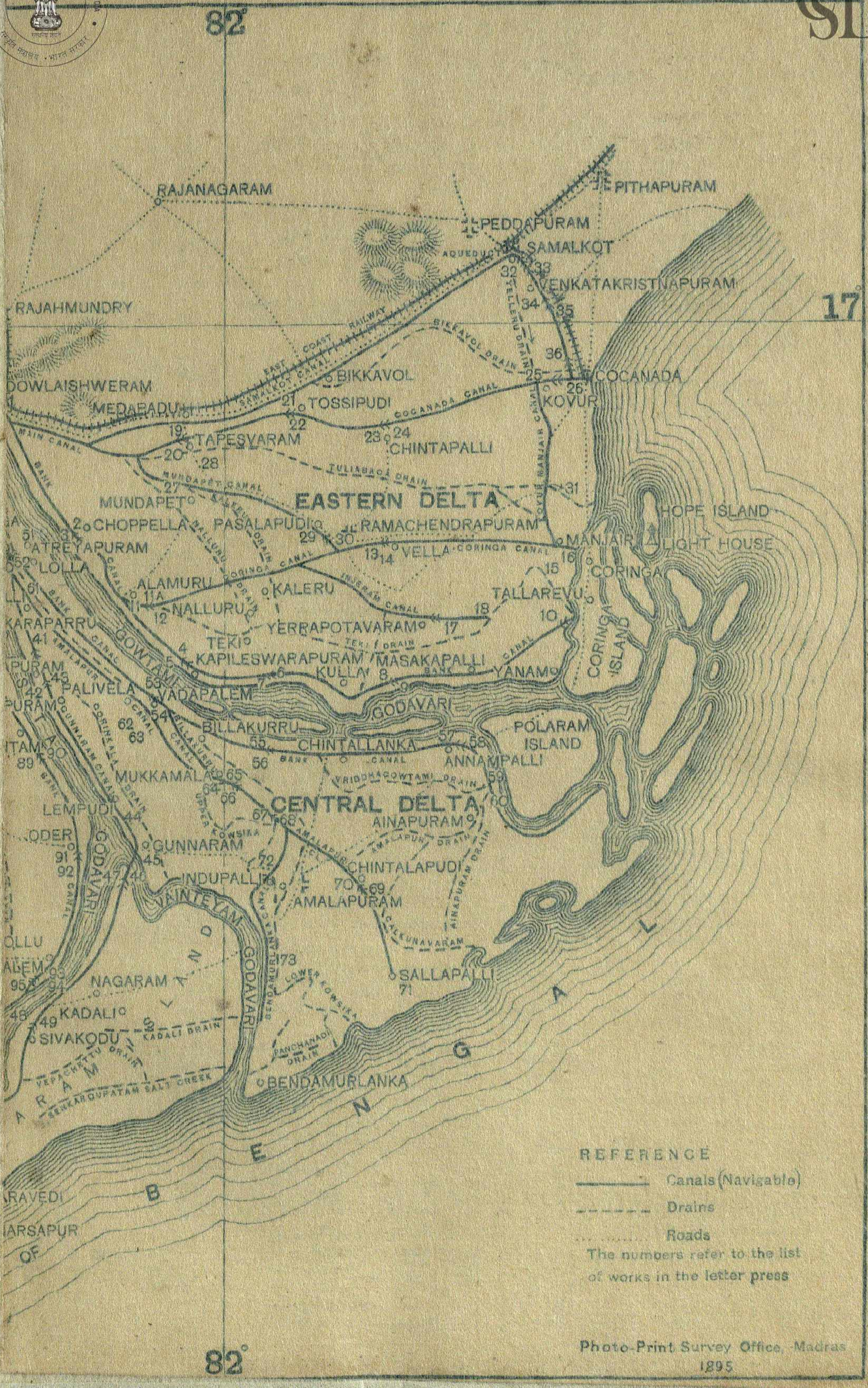

Photo-Print Survey Office, Madras
1895

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PRINCIPAL MASONRY WORKS,

Positions of which are shown on the Sketch Map.

EASTERN DELTA.

No.		M.	CH.
	MAIN CANAL.		
1	DOWLAISHWERAM HEAD SLUICE AND HEAD, DOUBLE, LOCK		
	BANK CANAL.		
2	CHOPPELLA LOCK	8	77
3	Do. LOCK WEIR	8	77
4	KAPILESWARAPURAM LOCK	16	0
5	Do. LOCK WEIR	16	0
6	KULLA LOCK	21	5
7	Do. WEIR	21	5
8	MASAKAPALLI LOCK	29	37
9	Do. WEIR	29	37
10	TALLAREVU TIDAL LOCK	39	40
	CORINGA CANAL.		
11	SURPLUS WEIR	14	10
11A	ALAMURU LOCK	14	11
12	Do. LOCK WEIR	14	14
13	VELLA LOCK	25	76
14	Do. LOCK WEIR	25	76
15	MANJAIR TIDAL LOCK	35	18
16	Do. LOCK WEIR	35	18
	INJERAM CANAL.		
17	YERRAPOTAVARAM LOCK AND WEIR.	30	4
18	WEIR AT END OF CANAL	32	78

No.		M.	CH.
	COCANADA CANAL.		
19	MEDAPADU LOCK	9	38
20	Do. LOCK WEIR	9	41
21	TOSSIPUDI LOCK	15	73
22	Do. LOCK WEIR	15	76
23	CHINTAPALLI LOCK	20	41
24	Do. LOCK WEIR	20	44
25	KOVUR TIDAL LOCK	29	28
26	Do. LOCK WEIR	29	24
	MUNDAPET CANAL.		
27	TAPESVARAM LOCK	11	39
28	Do. LOCK WEIR	11	40
29	PASALAPUDI LOCK	18	0
30	Do. LOCK WEIR	18	4
	KOVUR-MANJAIR CANAL.		
31	TULIABAGA DRAIN AQUEDUCT	33	67
	SAMALKOT CANAL.		
32	SAMALKOT LOCK WEIR	30	35
33	Do. DOUBLE LOCK	30	37
34	VENKATAKRISTNAPURAM LOCK	32	68
35	Do. LOCK WEIR	32	68
36	COCANADA TIDAL LOCK	37	9

CENTRAL DELTA.

No.		M.	CH.
	MAIN CANAL.		
37	BOBBERLANKA HEAD SLUICE	...	...
38	Do. DOUBLE LOCK	...	...
	GUNNARAM CANAL.		
39	RALLI LOCK	8	4
40	Do. WEIR	8	15
41	RAMACHENDRAPURAM SURPLUS WEIR	14	6
42	GOPALAPURAM LOCK	14	55
43	Do. WEIR	14	56
44	BELLEMPUDI SURPLUS WEIR	25	55
45	GUNNARAM AQUEDUCT	27	20
46	MONDEPULANKA LOCK	28	67
47	Do. WEIR	28	67
48	SIVAKODU LOCK WEIR	38	74
49	Do. LOCK		
50	SAKINETIPALLI TIDAL LOCK	45	40
	BANK CANAL.		
51	LOLLA LOCK	8	4
52	Do. LOCK WEIR	8	4
53	VADAPALEM LOCK	20	0
54	Do. LOCK WEIR	20	0

No.		M.	CH.
	BANK CANAL—*cont.*		
55	CHINTAL LANKA LOCK	27	0
56	Do. WEIR	27	0
57	ANNAMPALLI LOCK	39	0
58	Do. LOCK WEIR	39	0
59	VRIDDHAGOWTAMI DRAIN UNDER TUNNEL	42	46
60	KUNDALESWARAM WEIR	43	10
	AMALAPUR CANAL.		
61	RALLI SURPLUS WEIR	11	49
62	PALIVELLA LOCK WEIR	19	27
63	Do. LOCK	19	62
64	MUKKAMALA SURPLUS WEIR	25	45
65	Do. LOCK	26	1
66	Do. LOCK WEIR	26	1
67	NADUPUDI LOCK	29	68
68	Do. LOCK WEIR	29	68
69	CHINTALAPUDI LOCK WEIR	34	24
70	Do. LOCK	34	60
71	SALLAPALLI WEIR	39	78
	BENDAMUR LANKA CANAL.		
72	INDUPALLI WEIR	34	39
73	BENDAMUR LANKA SURPLUS WEIR.	38	5

WESTERN DELTA.

No.		M.	CH.
	MAIN CANAL.		
73A	VIZESWERAM HEAD SLUICE AND HEAD LOCK	...	...
74	CHETTIPET WEIR	6	8
	NARASAPUR CANAL.		
75	PERAVALI LOCK WEIR	16	22
76	Do. LOCK	16	26
77	ITEMPUDI LOCK	21	50
78	Do. LOCK WEIR	21	50
79	MARTER LOCK WEIR	22	17
80	Do. LOCK	25	23
81	KAVITAM LOCK WEIR	28	25
82	Do. LOCK	28	32
83	PALAKOLU LOCK	33	16
84	Do. LOCK WEIR	33	16
85	NARASAPUR TIDAL LOCK	38	14
86	MOGALTUR WEIR	46	2
87	Do. TIDAL LOCK	46	9
	BANK CANAL.		
88	KAKARAPARRU SURPLUS WEIR	17	3
89	SIDDHANTAM LOCK	25	7
90	Do. LOCK WEIR	25	7
91	KODER LOCK	31	45
92	Do. WEIR	31	45
93	LATCHMIPALEM TIDAL LOCK	40	39
94	Do. LOCK WEIR	40	39
95	NAKKALA OUT FALL SLUICE	...	...
	GOSTANADI AND VELPUR CANAL.		
96	GOSTANADI LOCK	7	37
97	Do. LOCK WEIR	7	44
98	VELPUR WEIR	21	60
99	MAMUDUR ESCAPE	30	0
100	Do. LOCK WEIR	30	79

No.		M.	CH.
	GOSTANADI AND VELPUR CANAL—*cont.*		
101	MAMUDUR LOCK	30	79
102	VISSAKODER LOCK	37	30
103	Do. LOCK WEIR	37	34
104	BHIMAVARAM TIDAL LOCK	41	47
	ATTILI CANAL.		
105	GODICHERLA LOCK	11	1
106	Do. LOCK WEIR	11	1
107	GUMMAMPAD LOCK	20	41
108	Do. LOCK WEIR	20	41
	VENKIAH AND WEYERU CANAL.		
109	DUVVA WEIR	14	0
110	PARIMELLA WEIR	20	79
111	Do. DOUBLE LOCK	21	17
112	CHINAKAPAVARAM LOCK	35	35
113	Do. WEIR	35	35
114	YELURPAD WEIR	45	16
115	Do. TIDAL LOCK	45	18
	UNDI CANAL.		
116	CHILAKAMPAD LOCK	19	74
117	Do. HEAD SLUICE	19	78
118	YENDAGANDI LOCK AND WEIR	27	60
	ELLORE CANAL.		
119	NANDAMUR AQUEDUCT	7	77
120	Do. WEIR	7	77
121	ELLORE LOCK	46	32
	JUNCTION CANAL.		
122	MUDDAPURAM DOUBLE LOCK	12	37

N.B.—*The Figures on the Map indicate the position of the works specified above. The mileages are from the Heads of the Deltas.*

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CHAPTER II.

THE GODÁVARI ANICUT—PROPOSALS AND SANCTION.

Towards the end of the first half of the present century, the Gódávari, or as it was then called, the 'Rajahmundry' district, had fallen into sad case. The abolition of the East India Company's factories and the competition of Manchester and other European looms had deprived it of nearly all its cloth trade, which had formerly brought into the district many lakhs of rupees a year, and given employment to a large community of artisans; an unsuitable form of land tenure, badly administered, pressed heavily on its cultivators; its few irrigation works were neglected; and it frequently suffered from droughts which withered the crops, or from floods which drowned them; for the noble river which runs through the district and now enriches it, then carried nearly the whole of its treasure of waters uselessly to the sea, or poured them in destructive floods over the most fertile parts of its delta.

More than a hundred years ago "* an Engineer (Mr. Topping) had observed the facility with which the Gódávari might be made to irrigate the districts on its banks, and had brought to the notice of Government how desirable it was to throw an anicut or dam across the river so as to raise the water and thus make it available for that purpose"; but the time and the man had not then come, and did not do so for half a century.

In 1832–33 a terrible famine ravaged the district, and the country had only partly recovered from the effects of this disaster, "† when the three unfavourable years of 1245 (1835–36), 1246 (1836–37) and 1247 (1837–38) were followed by the calamities of 1248 (1838–39) and 1249 (1839–40) and the almost equally calamitous season of 1250 (1840–41)."

The decreasing population and dwindling revenue now forced the Government into action, and in 1843 it sent one of its ablest servants, Sir Henry Montgomery, to inquire into the causes of the rapid decline of the district, and to advise as to remedial measures. In March 1844 he sent in his report. In it, amongst the causes, he gave prominence to "the abolition of the Government mercantile establishments and the subsequent annihilation of the cloth trade," and "the neglect of the existing works of irrigation and the absence of improvement."

With reference to the former he wrote thus:—

The abolition of the Government mercantile establishments and the subsequent annihilation of the cloth trade.

"37. The Government factories were abolished in ‡ fasli 1239 (1829–30). On an average, seven lakhs annually had been distributed for twenty-four years previous on their account. In some earlier years the annual disbursements amounted to 10, 11 and 12, and in one year exceeded 14 lakhs of rupees. It is impossible to suppose otherwise than that these large sums expended in the country greatly contributed to its prosperity, and that their being withheld from circulation has proportion-

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* 'Paragraph 258 of First Report of the Public Works Commission, Madras Presidency, 1852.'

† Sir Henry Montgomery's Report, 18th March 1844.

‡ 'Fasli' = Indian revenue year.

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ably had an opposite effect. Accordingly it is seen that the average land revenue for the fourteen years subsequent to the discontinuance of the Company's trade is Rs. 2,59,346 per annum or about fourteen per cent. less than in comparison with that of the same period previous to that event. For some few years subsequently the shock to the commercial community was partly alleviated by the excitement, which private enterprise received by the opening the Government withdrawal from commerce afforded, but in the last few years the main trade in cloth has been superseded by the European manufacture, and the fine punjams for which the district was once so famous are now not procurable. The annihilation of the once-flourishing trade has thrown out of employ a large body of weavers who formerly derived a good livelihood by their profession and contributed to consume the products of agricultural labour.

	RS.
Average of faslis from 1239 to 1252	16,12,826
Average of faslis from 1225 to 1238	18,72,172
Decrease ...	2,59,346

"38. In the fourteen years previous to the abolition of the factories, the average annual amount of specie remitted from this treasury was 10,59,235, of which 3,75,235, on an average of the same period, returned to the district for circulation within it. For the fourteen years subsequent to that era the average remittances have been 11,29,642 without any portion returning. It needs no effort of imagination to arrive at the conclusion that this heavy drain on the revenue and the cessation of the staple trade have had some effect, especially in the latter years, on the resources of the country, on the home demand for agricultural produce and consequently on prices. The marginal statement gives the annual value of the exports of piece-goods from fasli 1231 (1821-22) to the end of last year and shows a lamentable falling off in the five last faslis."

Value of Exports of Piece-goods.

Faslis.	RS.
1231 (1821-22)	9,74,075
1232 (1822-23)	6,53,730
1233 (1823-24)	5,97,492
1234 (1824-25)	7,03,193
1235 (1825-26)	14,10,756
1236 (1826-27)	9,25,857
1237 (1827-28)	9,64,595
* 1238 (1828-29)	7,71,526
1239 (1829-30)	6,56,743
1240 (1830-31)	2,33,392
1241 (1831-32)	5,80,506
1242 (1832-33)	4,85,564
1243 (1833-34)	3,57,550
1244 (1834-35)	6,35,901
1245 (1835-36)	4,91,502
1246 (1836-37)	4,37,451
1247 (1837-38)	4,08,819
1248 (1838-39)	2,26,768
1249 (1839-40)	1,94,515
1250 (1840-41)	2,11,353
1251 (1841-42)	1,67,212
1252 (1842-43)	1,95,312

Fortunately Sir Henry Montgomery had been Collector of Tanjore, where he had seen the blessings bestowed on the district by the irrigation from the river Cauvery, and the astonishing improvement which had followed the building of the Coleroon anicuts in 1835. He, therefore, when dealing with the remedial measures required for the 'Rajahmundry' district, strongly urged the thorough examination of the Gódávari delta by an experienced engineer, with a view to the development of its irrigation resources. "My own impression," he wrote, "leads to the opinion that much may be done with the Gódávari, both in improving the means of cultivation in adverse seasons when local rains fail and in counteracting the ill-effects which follow an over-abundance"; and in the same report he says: "Objections have been raised to the undertaking of any extensive works on the grounds of the difficulty of controlling the Gódávari, which has been designated by Mr. Smith,† as 'a river which in one year ensures a full crop without any superficial aid whatever, in another is utterly destructive of crops and works by its inundation, and in another could not be made productive at any expense.' It cannot be denied that the Gódávari when filled, as it was in the early part of the present season, is a fearful stream, overflowing the country through which it passes and carrying before it all improvements in its course; but it must be remembered that no endeavours have been made to diminish the extent of mischief it thus occasionally causes, by diverting a portion of the body of water from the main stream and distributing it into irrigation channels throughout other parts of the country, or by maintaining the river banks in a state of efficiency. The presence in the Northern Circars of Captain A. Cotton, whose acquaintance with the management of river irrigation on an extended scale has been successfully applied to the southern districts, seems to afford an opportunity deserving of being embraced by the Government to obtain a satisfactory opinion on this important subject."

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* Cessation of Company's trade.

† The Collector of the district.

The Madras Government at once acted on this advice and in August of the same year (1844), Major Cotton (now General Sir Arthur Cotton) of the Madras Engineers, to whom Tanjore owed the construction of the Coleroon anicuts above referred to, sent in his 'Report on the Irrigation of the Rajahmundry district,' from which the following extracts are given:—

1. "The principal part of this district forms the delta of the Godavery, and as respects soil, climate, and capabilities of irrigation, it can scarcely be surpassed by any part of the world. Such tracts as this, with their immense natural advantages, yet absolutely require the following four kinds of works, before their resources can be in any good degree developed. Even though favoured with a good supply of local rains in general, as is the case with this delta, probably not one-fourth of the produce of which they are capable can be obtained by means of local improvement of villages on a small scale, without the aid of the main works now enumerated:—

"*First.*—The embankment of the rivers, to secure the crops from destruction by the river floods.

"*Second.*—Dams, with channels of irrigation leading from the river, to bring its water from the level of its bed to that of the surface of the land.

"*Third.*—Surplus channels, to lead off the floods caused by the local rains, from the flat lands to the sea.

"*Fourth.*—Raised roads and bridges, to allow of the conveyances of produce to the markets, and to the coast, through a country which is otherwise, from its nature, impassable during the rains.

"It needs no argument to convince that, without these means of counteracting the irregularity of the natural supplies of water, and of providing for the removal of produce from where it is grown, to the places where it is required for consumption, or exportation, only a small portion of what the tract is capable of producing can be secured. One year a portion or the whole of the crop of large tracts is destroyed by the overflowing of the rivers, another year the same losses are sustained from the rivers not rising high enough, though even in the worst years it may contain water enough to irrigate ten times the extent of land forming the delta; in a third year, the lower or flatter tracts are so flooded by the local rains that the labour of cultivation is all thrown away; in another, the crop is destroyed by a failure of the rains over three-fourths of the district, when not an acre of it need to be dependent at all upon them; and it may happen that the district is suffering from two or three of these visitations at the same time, for instance, one-half of the district suffering from river floods, while the other half is equally distressed by a failure of the local rains; and lastly, the most abundant produce is of little use, unless it can be conveyed at a moderate expense, and at *the proper time*, to the point where there is a market for it.

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2. "Of all these four works, Rajahmundry has been hitherto, and is now, wholly destitute. It is entirely without any general system of irrigation, draining, embankments, or communications. There are some partial works of this kind, but they are of small extent, and even these have not been kept in an effective state. In the last three or four years, something has been done towards the repair or improvement of the old works, but their complete restoration is not what the district needs; it is the execution of a system of works of a general nature, without which all minor works can effect hardly anything, comparatively speaking. It is truly astonishing to see this important district in this state, and the more so when considered in connection with Tanjore, a district of the same kind in the same presidency. In the latter, from the time it came under the management of our Government, there has been one continued process of improvement carried forward, so that it may now be said to be completely provided with works of all the four kinds above mentioned (though many works of detail may yet be executed with advantage). In Tanjore, when the supply of water in the river is scarce, every drop is led out on the lands; in the severest freshes there has not been any considerable extent of loss sustained by the overflowing of the rivers for the last ten or fifteen years; only a very small part of the district ever suffers materially from the heaviest local rains, while the crops are so independent of these, that a failure of them, comparatively speaking, but little affects the produce; and lastly, there is a communication for bandies open throughout the year from every talook to every other talook, and to the coast. The results in the two districts correspond with the difference in the attention that has been paid to them. The Delta of Tanjore contains a population of about 1,100,000 and pays a revenue of about 45 lacs with so much ease that it has been constantly showing an increase of everything which indicates the prosperity of the inhabitants, though it has had no valuable article of export except rice; while Rajahmundry contains in the whole district only 560,000, and probably in the delta not more than four lacs, and pays at present with great difficulty 21 lacs. The Delta of the Godavery is indeed smaller than that part of the Delta of the Cauvery which is in the Tanjore district, but, on the other hand, the quality of the land is, on an average, decidedly superior in the former; it is also much more favoured in respect of its local rains; and the supply of water by the river is probably four times as great and much more constant.

* * * *

3. "I have not yet received a statement of the revenue of Rajahmundry from the time it came under our Government, but in the last ten years I find it has fallen off about five lacs, while the population, if the returns are correct, has fallen from 740,000 in 1821 to 560,000 in 1842, or one-fourth in twenty-one years. This very rapid decline is no doubt mainly owing to the failure of the cloth trade, which in ten years has fallen from about seven lacs of rupees to three lacs, and which I am told was once much higher. A diminution of export trade to the value of four lacs would throw out of employment about one lac of people, and a large proportion of these no doubt would emigrate; but the amount of suffering in the district, which must have followed upon such a decrease of employment for its population, it is impossible to conceive. How far the loss of this trade would have been prevented or delayed, had the irrigation of the district been attended to, is a point deserving of most serious consideration. The price at which any article of trade can be supplied in any country must depend mainly upon the rate at which food can be obtained, and upon the price alone depends the admittance of any article into a particular market. Had rice been obtainable with less labour, when the English cloths begin to undersell those from these districts, the Indian cloth might have been sold at a lower rate, for everything must depend upon the price of food.

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"In Rajahmundry, I have no doubt that a complete system of irrigation would increase the produce from the lands now cultivated by one-half, and that with greatly diminished labour; so that food could be produced at one-half the cost it now is, a difference, which I have little doubt, would for the present at least restore a portion of the cloth trade. It is not, therefore, in my opinion, sufficient to say that the loss of the cloth trade has caused the late diminution of revenue and population in the district, without inquiring further, whether that cause itself is not in a great measure the effect of neglecting those means of improving the district which we had in our power. But whether the cloth trade revives or not, it is certain that, if food is produced with less labour, the prosperity of the district must increase; either the food itself will become an extensive article of export, or something else will be produced or manufactured with advantage in consequence of the abundance of food. In this case, however, there can be no doubt that sugar will become the great export of the district, on which subject, however, I have already communicated with the Board. There is already a very considerable extent of sugar cultivation in the district, and nothing wanted but the establishment of extensive sugar works to increase its cultivation to any extent, provided that the district is irrigated. I am happy to say that the immediate establishment of sugar works in the district is now, I believe, determined upon by an English mercantile house.

* * * *

5. "The results in Tanjore, compared with Rajahmundry, place in the strongest light the consequences of the two different modes of proceeding. If we take the increase of revenue in Tanjore at 16 lacs, and consider it to have been progressive, as it has been upon the whole, the total additional revenue in forty years was 320 lacs, and the total irrigation expenditure 32 lacs. I have not the statistics of Rajahmundry yet for so long a period, but I believe the revenue has not improved; and in the last ten years, there has been a falling off of five lacs a year, or a loss of 25 lacs in all. I have not the smallest doubt that, had one-quarter of this been spent on the irrigation, the whole 25 lacs would have been saved; and I am equally certain that, had that whole amount been expended from the time the country came under our control, the revenue would have been double what it now is;—I do not mean to say that it was possible, many years ago, to have introduced a complete system of irrigation into the district; the zemindary system would have opposed immense obstacles to it, though much might doubtless have been done. But now the time appears to have come when the Government may take the matter in hand without any doubt of being able to go through with it. Many of the zemindars are much more sensible than we are of the importance of such an undertaking, and if there are any still remaining who would be inclined to throw any obstacles in the way of it, they are quite powerless; arrangements must of course be made with them, either to pay a share of the cost of the main works, proportionate to the extent of land watered, or to pay an increase of peshcush; but I have no doubt that, under judicious management, these points could easily be arranged.

6. "I would next proceed to consider the nature of the works now in existence and those which would be required. There are a few large irrigating channels from the river, but they are radically defective. Their beds are so much higher than that of the river, that they only admit water in the high freshes; and hitherto they have been without head sluices, so that the crops dependent upon them might be at one time perishing from drought, though there was an immense body of water in the river, and at another drowned by the floods they conveyed to them, and not those lands only, but all the neighbouring country also. The Bhoopiah Calvah I found to be about 14 feet above the level of the bed of the river, so that nothing but a high fresh could reach it; and last year, it was evident from the appearance of the channel a torrent of water passed down it, overflowing its banks and flooding the whole country. This latter evil is now

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counteracted by the erection of the head sluices, which is a great improvement, but it only removes the smallest evil of the two to which such a channel was subject. These imperfect river channels, which also only lead water to a small part of the district, are the only irrigating works of any consequence in the delta. There are also some low and partial embankments to the river, but so utterly inadequate that several lacs of rupees were lost last year in the destruction of crops by the river floods. There has been some considerable improvement made in these this year, but a very large amount of work is required to put them in an effective state. A good deal of work has been done to the great line of road through the town of Rajahmundry, but this can hardly be said to be in the delta; it is however in a very imperfect state and wants many bridges. About twenty years ago, Mr. Robertson estimated for completing the water communication by the creeks and backwaters near the coast, from the northern end of the district to within a few miles of Masulipatam, a most important work; it was estimated at only 7,000 rupees, but was not completed, though one or two of the cuttings were made.

7. "The works that will probably be required may be thus roughly estimated.

	LACS.
Annicut across the Godavery above Rajahmundry	4
Two main irrigating channels	5
Aqueduct to convey water across the river to the tract lying between the two branches	2
Detail works, channels, sluices, &c., in the Circar tracts	2
River banks	1
Cutting bends, &c., in the river	½
Roads and bridges in the delta, 200 miles at 1,000 rupees per mile ...	2
	16½

8. "This is of course only a rude judgment of the works and their cost, merely intended to show the sort of plan which I would recommend. The principal difficulty to be encountered in this district, is the bringing the water from the level of the river to that of the lands. This is owing to two things, the great depth of the channel of the river (about 25 feet at the head of the Bhoopiah) and the moderate fall of its bed; about one foot per mile. These two will make it necessary to have both a high annicut and a considerable length of channel, with deep cuttings to lead the water out to the surface of the lands. I have not, however, examined the river above Rajahmundry. I have no doubt of finding a good site for an annicut, as respects materials, for the hills come down to the bank of the river, and I saw an excellent kind of granite at Rajahmundry, brought a few miles down to the river. I am also inclined to think that when a few levels have been taken, I shall find the country more favorable for the channels than I have supposed in the above estimate.

"The southern channel will not merely provide water for the southern part of Rajahmundry, but also for a very large portion of Masulipatam, sufficient, I suppose, to yield six or eight lacs of rupees when properly irrigated.

"The central tract between the two main branches of the Godavery is, I understand, the richest in the delta, but I know of no way in which water can be conveyed to it, but by carrying it from one of the main channels over one branch by an aqueduct. This would be an expensive work, but a bridge would be combined with it which would be an incalculable benefit to the district.

"The river banks will not be very expensive; there was destroyed last year, by the flood, probably three times as much work as is wanted to put them into an efficient state.

"The channel of the river has been hitherto totally neglected; it has been allowed to wander wherever it would; and, what is worse, the inhabitants have been allowed to encourage the formation and growth of islands in it, the conse-

GSL

quence of which is, that it cuts into the land opposite, which is very like permitting one man to rob another. In the lower part of the southern Godavery, a bend has been allowed to form, which has cut away the greater part of the town of Moddapollem, and if neglected, will destroy both the remainder of it and the adjoining town of Narsipoor. Two vauganies were constructed this year for the protection of the town; they are well built and will be of great use, but, more are required; and to check the evil effectually, the bend ought to be cut away. This is also absolutely necessary on account of another evil arising from it, viz., that it keeps the surface of the river so high in the floods. It is exactly similar to a bend in the Colleroon, near the sea, which was cut away about three years ago.

"The roads and bridges will have a most powerful effect upon the prosperity of the district; for several months grain, jaggherry and other bulky articles cannot be moved at all, unless produced near the banks of the rivers; and for several more, the cost of transport is enormous. Supposing that one anna per ton per mile were saved by the construction of good roads, and that 45 tons a day were conveyed by them, there would be a saving to the district of two lacs a year on the 200 miles of road, besides all the advantages to travellers, and the incalculable effect of being able to convey produce to the markets at the proper time. In Tanjore, on one of the raised roads, the traffic was found to be 1,200 male travellers, and near 100 tons of goods per day. It need hardly be urged that, if the people were relieved from a burden of two lacs a year, in the transport of goods, the effects of it would be very sensibly felt on the revenue.

"I have not supposed that any of the large rivers are to be bridged, though I would undoubtedly continue annually to lay out a large sum on that work till the communications were completed. From the cheap rate at which excellent timber of various kinds can be obtained in this district, I am in hopes that bridges upon the plan of the American timber bridges would be found very moderately expensive, but I have not yet been able to get one estimated.

"This sum of 16½ lacs might be expended in four or five years, and would, I should hope, convey water to all parts of the district; but there would be a demand for additional works of detail for many years, as cultivation extended and population increased. I have not the least doubt that it would very soon yield cent. per cent., nor that, if an effective system of irrigation were fully established and kept up, the revenue of the district would rise to 50 lacs of rupees.

"In examining the question of the propriety of such an outlay as this, there is one point which I consider deserving of particular attention; we are apt generally to think of a Government expenditure, as if it were precisely similar to one made by a private individual. But in countries circumstanced as these are, there is a vast difference, and especially in this particular case of Rajahmundry. A lac of rupees cannot be spent in any district without a large portion of it immediately finding its way back to the treasury; but in this district which is now suffering such difficulties from the immense diminution of specie, probably the greater part will be paid back in the course of the year. This additional circulation will enable many to pay their kists, who otherwise could not have done so, and perhaps there would be little more difference made by its disbursements in respect of the state of the treasury than that such a portion of the population as would otherwise have been either not at all employed, or to little effect, would thus be usefully occupied. During three or four months the great bulk of the population are employed to very little purpose, where there is almost literally no capital to enable the land owners to make improvements; but an expenditure of three or four lacs a year would put life and activity into the whole district. That part of the population which is just now, from the impoverished state of the district, a dead weight upon the rest, from want of employment, would be provided for, and the supply of specie would give a great stimulus to the remainder. Indeed, I would state it as my opinion that, independent of the ultimate returns, the treasury would not be at all the poorer at the end of the year for such a disbursement in the present state of the district. Such an outlay seems to me more nearly allied to a loan from a landlord to his tenant, to be expended in improving his farm, than to a simple expenditure.

"As for the proper returns from the works executed, they would not certainly be so immediate as in Tanjore (where I believe, almost without exception, the money was repaid in increased revenue within the year), because it probably will be found impossible to execute the main works within three years; but I have no doubt that, if the works are diligently prosecuted, before five years are over a very large increase of revenue will be obtained.

* * * *

"As the fundamental work in the system of irrigation here supposed, viz., an annicut across the Godavery, may appear, in consequence of our having as yet attempted scarcely any thing worth the name of a work of magnitude, a very serious undertaking, if not an impracticable one, I would say a few words on that point. First, let us observe what has been done; the two Colleroon annicuts, one 650 yards long and one 750, with locks, sluices, &c., were both built at once, and each finished, notwithstanding the presence of considerable stream of water, in exactly three months from the time of its commencement; the one costing near a lac and the other about 85,000 rupees. The completion of one of them within two years was looked upon by most people as a vast work, and what could scarcely be hoped for. The present work would contain probably double the quantity of materials of these two together. But I expect to be able to choose a site for it, where there will be abundance of suitable stone close at hand, which will greatly facilitate the work, and I think it is worth considering whether it might not be constructed of rough stone chiefly. The low rate at which we have been able to do this work at Vizagapatam, even with the comparatively imperfect apparatus we have used (viz., wooden rails and 2-ton cranes) encourages me to think that we might construct an annicut in that way cheaper than any other; and it would have many advantages, chiefly that it would be done almost entirely by ordinary labourers; for in a district where so little masonry work is generally going on, it would be very difficult to collect so many artificers as would be desirable if the annicut were formed entirely of brick and squared stone. With waggons, rails and cranes calculated for 10-ton loads, or even 5 tons, it could be executed with great expedition and very cheaply. By this mode of construction also, what would probably be the main obstacle would be overcome without any trouble, that is, the disposal of the large stream of water, which flows down the river even in the hot weather; this would find its way through the open stone work, while it was under construction, and a lining wall along the upper face of the dam could be added afterwards. The body of a dam 2,000 yards long, 50 broad, and four high, on the average, could be formed for about two lacs of rupees, and it could be finished by a covering of cut granite afterwards. The channels might be cut to the full depth, and of a moderate width, the first year, so as to allow the water to flow down them, and they might be gradually widened, by which means early returns would be obtained.

"There does not seem to be any use in my attempting to go further into this subject at present, till I have obtained the necessary materials for a more complete report; and I would therefore now only request the Board to place at my disposal the means I require to examine the district thoroughly and without waste of time; and I would take the liberty to remind them, that my own health and strength are such that I am utterly unable to do more myself than visit the various localities and prepare plans and estimates from the materials provided for me by others. Surely, it is time to take decided steps to restore to prosperity a district which has so sunk under our management during a long series of years; a district which in itself has such capabilities as can scarcely be equalled, if at all, in any other tract in the world; having all the advantages of Tanjore with a richer soil, a far nobler and more certain river; and in addition, what is certainly not to be found in any other country, a perfectly accessible and safe port, directiy connected by a large river with forests of teak of the finest quality. That such a district should have greatly retrograded under our management is one of those things which it is impossible to explain." . . . .

Eight months later Major Cotton sent in a 'Second Report on the Delta of the Gódávari,' dated 17th April 1845, from which the following are extracts :—

"The first report on the irrigation, &c., of this tract pointed out the neglected state of the district, its destitution in respect of those artificial works which are absolutely necessary to develop the vast capabilities of these rich alluvial lands, and the consequences of such neglect in comparison with the results of a liberal system of improvement, as shown in the Delta of the Cauvery. It required neither time nor attention to discover so far what was required for this unfortunate district. What it wanted was only what every delta requires, and without which such tracts, with all their prodigious natural advantages, are subject to more dreadful evils than many less fertile districts. If such countries are left to the mercy of the great rivers that flow through them, the water at one time many feet above the surface of the land, and at another 20 or 30 feet below them—in one month, during a certain crop, deluged with rain and river floods combined, and before that crop is cut (if any of it escapes), exposed to a perfect drought, an impoverished people, and empty treasury are the inevitable consequences. The question therefore is, merely, how the necessary works may be most economically and effectually carried out. It is rather the question how a man may be best clothed and fed, than whether he needs clothing and food. On my return to the district, therefore, after the monsoon, I proceeded to the examination of the river and the lands, in respect to their levels, the rise and fall of the water, &c.; the first and fundamental point to be ascertained being the proper site and cost of an annicut. It must be acknowledged that, before looking closely into the subject, this appeared to be a formidable undertaking in consequence of the great depth and breadth of the river, both so much exceeding those of the Cauvery and the Colleroon, the rivers which I had been accustomed to; and the idea of building a dam across a river, where it is more than seven times the greatest width of the Mississipi, might very naturally seem a doubtful project. This case is, however, a remarkable instance of the vast difference there may be between the distant superficial view of an object and that which we may obtain by an actual examination of it. Upon a careful survey of the river, I find that not only is such a work as an annicut practicable, simple, and easy, but that such are the extraordinary natural facilities for its construction, at the site where it could be most beneficially constructed, that its cost, in comparison both of its great extent and the vast effects which it is calculated to produce, would be really very moderate. I here propose only so far to touch upon the subject of the levels of the river as may be necessary for the explanation of the subject in a general way.

"The Godavery, rising near Bombay, passes for several hundred miles through an open country, watered chiefly by the south-west monsoon. About 200 miles from the sea, it enters the hilly tract that runs at the back of the Northern Circars, and at 60 miles from the sea it enters the alluvial country which it has itself formed. It seems very remarkable that, in passing through the great barrier of hills (I find from information which seems to me conclusive), it has so effectually made its way that there are no falls throughout the whole length of its channels, nor indeed any obstructions of consequence. Such is the statement of the boatmen who navigate the river, and it seems to be completely confirmed by the fact, that the timber rafts never come down from the Hyderabad country except when the river is almost at its lowest, and has not more than two or three feet of water at the fords in the low country. The alluvial land does not immediately expand to a great width from the point at which the river leaves the main range, there being still rising grounds and detached patches of hills, at a distance of from half a mile to five miles from the river, for the distance of 23 miles further; at the end of which distance, two or three detached hills come close to it, the river divides into two streams, the alluvial country spreads out on both sides, and the delta may properly be said to commence, extending on the west side till it meets that of the Kistna at the Colair lake, about 40 miles, and in the east side about 32 miles to the shore of Coringa bay, where the coast runs for some distance nearly north and south.

"Within the line of the hills the river has, I conclude from the above-mentioned fact, a very moderate fall; and I saw that such was the case for some distance within. From the hills where the alluvial land immediately adjoining the river is 80 feet above the level of the sea at high water, spring tides, it has a most regular slope, commencing with a foot and-a-half per mile, and gradually diminishing to one foot as it approaches the sea. The rise and fall of the river there is 38 feet, and as the rise of the river is reduced to nothing at the sea, it follows that the summer surface of the river must have a less fall than that of its banks to that extent, viz., 38 feet, so that at Palaveram, where it leaves the hills, the summer level is only 42 feet above high water, and the bed at the ford there only 38 feet. But the fall of the bed or even of the summer surface of the river is by no means regular like that of the surface of the floods and that of the land. Between the fords there are deep hollows, one I measured 30 feet deep in summer, another 26 feet; and in one place I found a slope of nine feet in three miles in the summer surface of the water; in another only one and-a-half foot in four miles. The average from the hills to the sea is seven and-a-half inches per mile. At the head of the delta, the bed at the ford is 22 feet above the sea, and the distance being 38 miles in a direct line, the average fall measured in that way is seven inches a mile; but if the actual length of the river, viz., 50 miles is taken, it is only five and-a-quarter inches.

"Besides the slope of the land towards the sea in a delta, it has another slope, viz., a fall from the river in a direction perpendicular to its course, and this fall is much more rapid than that towards the sea. In the present case it has been ascertained to be in one place, viz., soon after the river leaves the hills, 18 feet in one and-a-half miles, to where it meets the adjacent hills on the east side. In another, on the west side, about four miles from the hills, eight feet in three-quarters of a mile. Near the head of the delta, 16 feet in two miles on the west, and seven feet in two and-a-half miles on the east side. Thirteen miles further down, that is, 25 miles from the sea, the fall is nine feet in two and-a-half miles on the west side of the Godavery. Thus, the river banks form a ridge from 18 to seven feet above the level of the land, at the distance of from three-quarters to two and-a-half miles distant on either side, providing, most remarkably, for the leading out of the water upon the lands. The slope of the country towards the sea, at the foot of the ridge, is uniformly one foot one inch per mile on the west side, all the way from near the hills. On the east side, the distance being shorter, to the bay of Coringa, the fall is one and-a-quarter foot per mile, from near the head of the delta where the Dowlaisweram hill closes in the bank of the river.

"The upper part of the great mass of the delta land is under 30 feet above high water, hence there is comparatively little to be gained by having the top of the annicut more than two or three feet above that level. Further, the slope of the bed being quite irregular, while the slope of the banks is perfectly regular, it follows, that the rise and fall of the river, or its depth in the high freshes varies considerably at different places, besides that on an average it diminishes all the way to the sea. Thus at Palaveram its rise and fall is 38 feet; at Rajahmundry 20 miles lower it is about 31 feet. At the head of the delta four miles lower only, 27 feet. At the head of the Bhoopiah channel, 11 miles further down, 27 feet. The level of the land on the banks generally is about two feet below that of the highest floods that have occurred in this century.

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"Thus, the apparently formidable operation of bringing the water from the bed of a river more than 40 feet deep (as it is at Polaveram) to the surface of the lands, is upon an examination of the level, reduced to this, that the highest part of the delta is only eight or 10 feet above the bed of the river in its immediate neighbourhood; that is, within two miles of it; and that, if an annicut be built 11 feet high above the deep channel of the river, the deepest excavation for the irrigating channels will be only 18 feet; and within two miles, the country on the west side would be below the level of the top of the annicut. On the east side, the lands would be on the same level within about four miles. The apparent objection arising from the great depth of the river is thus completely disposed of.

"The breadth of the river varies from about 2,000 yards, or one mile and one furlong, to 6,000 yards, or nearly three and-a-half miles, which latter breadth, however, includes islands to the extent of about 1,000 or 1,500 yards. This great breadth cannot be avoided, but there are everywhere great facilities for constructing an annicut, from the nearness of the hills containing good stone and lime, and especially at the head of the delta, there is a hill of a most suitable kind of stone, and hydraulic limestone of excellent quality in abundance in the immediate neighbourhood. From these advantages and the low price of labour in the district, a vast mass of masonry may be executed for a moderate sum. The difficulties to be encountered in building an annicut in an alluvial country are no more than what we have always met with in Tanjore, while, on the other hand, we have a great advantage here in a much lower velocity of water; the fall at the head of the Delta of the Cauvery being three and-a-half feet per mile, and in the Godavery only one and-a-quarter foot, which will make a very important difference in the power of the water to injure such a work.

" Having thus taken a general view of the nature of the river, and the facilities it offers for works to lead off its waters to the lands, we may consider the extent, quality, and present state of the lands to be watered. The Delta of the Godavery extends from Samulcottah on the east to the Colair lake on the west, where it meets that of the Kistna. This whole tract, with the exception of a strip of sandy land bordering on the sea, is one noble expanse of rich alluvial land fit for almost any cultivation, if supplied with water, and decidedly richer on an average than Tanjore. It contains as follows:—

	SQ. MILES.
East of the Godavery	450
Between the two main branches	550
West of Godavery and within Rajahmundry district	700
West of Godavery in the Masulipatam district as far as the Colair lake	300
Total ...	2,000 or
Acres ...	1,300,000

and deducting one-fourth of this for sandy tracts near the sea, sites of villages, channels of rivers, &c., there remain 1,000,000 acres of land fit for cultivation with paddy or sugar. For this there is an ample supply of water in the Godavery, on an average of the last three years, for one hundred and twenty days in the year, when it stands not less than five and-a-half feet on the Rajahmundry standard; that is, during the months of July, August, September and October, without a day's intermission, which is sufficient time fully to secure the rice crop. I have not been able to ascertain correctly the supply of water during the summer, but from what information I can obtain, I think there must be considerably more than enough to supply 100,000 acres of sugar. Besides the extent of land above-mentioned, the waters will be conveyed to the Colair lake, the bed of which, and all the land bordering on it, about 500 square miles, would thus be watered. Indeed there is no reason why the water should not be led all the way to the Kistna, the channel terminating on that river at 15 feet above the high water, which would allow a fall of three inches per mile, from the Godavery,

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and include a breadth of about 20 miles between it and the sea at Masulipatam. A further extent of about 500 square miles would thus be brought under the annicut, making a total of at least 3,000 square miles. The quantity of water in the highest freshes of the Godavery I calculate to be ninety times as much as would be required for the whole of this tract, and there would be abundantly sufficient for a rice crop every year for such a length of time as would secure it completely.

"We thus easily establish these three fundamental points—

"*First.*—That there is an ample supply of water for a rice crop in all the land forming the Delta of the Godavery, and as far as the Kistna also; and there is certainly water enough in the river for a very large extent of cultivation, probably not less than 100,000 acres, all through the dry season.

"*Second.*—That there is a vast extent of rich alluvial land, not less than 820,000 acres within the district of Rajahmundry, and nearly as much in Masulipatam, taking in the whole tract as far as the Kistna, to which the water may be applied.

"*Third.*—That by means of an annicut of a very moderate height, and main channels only two or four miles in length, the last drop of water in the river may be brought to the surface of the country at a level which will command the whole of the above-mentioned tract.

"*Fourth.*—We may consider also the practicability of the construction of an annicut (omitting for the present the question of its cost) fully established by the same thing having been already effected in similar instances in the two Colleroon annicuts, the difference of such a work standing being decidedly in favour of the Godavery, viz., the velocity of the river being only about three-fourths of that of the Colleroon at its head, which more than compensates for the greater height that is above proposed for this work, the Colleroon annicuts having been only six and-a-half and eight feet high.

"There seems no possible room for doubt on these fundamental points, and we may, therefore, proceed at once to consider the remaining questions; which appear to me, *first*, whether any evil can arise out of such a work as a dam across the Godavery, and, *secondly*, what the cost and returns would be.

"The annicut will be situated similarly to the lower Colleroon annicut, extending quite across the river. Its only effect, therefore, must be to raise the water in the river above it; but it will not raise it to the same extent, owing to the very low velocity of the river. If it be built at the site I propose, and 11 feet high above the deep channel of the river, it will close up about two-sevenths of the whole water way of the river in high floods, which, with so low a velocity as three and-a-half miles per hour, would scarcely cause a perceptible elevation of the surface of the water above it.

"When the water in the channel of the river below the annicut is just level with the top of that work, I calculate that the upper water will be raised to about one and-a-half foot above the crown; and this difference of level between the water above and that below the work must of course diminish as the river rises, and in severe floods the difference of level will be reduced to two inches. With respect to its effect on the bed of the river, the ordinary effect of such work is, of course, to raise the sands on the upper side and to produce deep excavations on the lower. The former is a very serious evil, and unless counteracted, the tendency will be to fill the irrigating channels with sand. The principal means proposed to prevent this, is the construction of six ranges of under sluices, of 40 vents each, their floors level with the apron of the annicut and eight feet below its crown. Four of these to be placed near the heads of the irrigating channels, and the whole of them left open whenever there is water in the river to spare. The influx of sand into the channels will be further checked by leading them off at right angles with the river, and as much out of the set of its current

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as possible; and also by making the heads of the channels capacious, so that the water may enter them with too low a velocity to carry much sand with it. The other effect of the excavation of deep pools below the works affects only the stability of the work itself. The operation is greatly checked by the section given to the work, similar to those in the Colleroon. By making the body of the work nearly perpendicular on the lower side, and laying an apron sufficiently strong to bear the overfall of the water, its force is so greatly broken that but little effect is produced in the bed of the river below; and the remainder is counteracted by an ample apron of loose stones of large size, beyond the solid apron, which must always be the grand protection of such works as sluices and annicuts in a delta, where there is nothing more solid than sand around and beneath the works.

"The annicut will certainly have an important effect in one respect, viz., in obstructing the navigation of the river in the low freshes; and the extent of the navigation is very considerable. This difficulty is provided for in two ways; first, the irrigating channels will all be also navigable, and will form an internal water communication of the most complete kind, intersecting the whole country, and entirely free from the serious drawbacks to the present communication by the river, viz., the sand banks, want of towing paths, heavy ripples, and, in the dry season, shallowness of water besides many others. The main channels will have water in them the whole year round, and there will indeed be nothing wanting to make them effective lines of navigation; but at the same time for boats and timber that may be required to pass down or up the river, when there is neither so much water as to allow of their passing over the annicut, nor so little as to prevent their navigating the river, locks are proposed to be constructed at the heads of the irrigating channels to pass vessels round the annicut.

"The main question now remains to be considered, viz., whether the cost of the works will be repaid in their effect upon the district?

"The estimate for the works now proposed, viz., an annicut, the head sluices for two main irrigating channels, viz., one on the west side of the river and one at the head of the central tract (the upper part of which is called the Rallee estate) locks at each end for passing boats round the annicut, and those for carrying them past the head sluices into the irrigating channels, and the partial clearing of the present channels (which is all that is included in the present estimate), amounts to—

	RS.	A.	P.
Annicut with six sets of 40 Under sluices	3,88,004	2	0
Five locks	18,419	6	0
Two head sluices	13,148	8	0
Excavations	14,000	0	0
Superintendence	12,000	0	0
Contingencies, &c.	30,000	0	0
Total ...	4,75,572	0	0

"This sum is very small, whether the magnitude of the work or that of the expected results is considered. The length of the annicut will be 4,200 yards; and it will be seen by the plans that I propose to build it on a substantial and permanent plan, so as to be nearly independent of periodical repairs. The extraordinary advantages of the site will enable us to execute the work at a moderate cost. There is a hill of coarse, strong sandstone close to the spot. This stone is of a degree of hardness exactly suited to the case, neither too hard to be expensive in working, nor yet soft enough to be unfit for the purpose. There are also several hundred thousand tons of broken stone, the accumulation of ages from former quarryings, which will exactly suit for rubble work. All this latter material therefore will cost nothing but the carriage, and it is within 800 yards of the end of the annicut. As if everything should concur to facilitate the work, we have further in the immediate neighbourhood abundance of first-rate hydraulic limestone. There is also teak to be had in any quantity and of excellent quality

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at about 10 annas per cubic foot, including carpentering, for the lock and sluice gates. The cost of the masonry work, omitting the carriage, I have estimated at the rate at which it can be executed at present; but there is every reason to believe that, on a large scale and under European superintendence, the cost of every part of the operations may be considerably reduced. This part of the country is nearly without masonry works of any description, so that the natives are far behind those of the southern districts in all their modes of executing them. For instance, they burn their lime in heaps on the open ground, not even using a kiln of any kind. In such a state of things it is not to be supposed that under European superintendence the cost cannot be diminished. For the carriage of materials, I propose to use rails, as I have done with such good results in the execution of the bulwark at Vizagapatam, even though nothing but wood was used, with wooden wheels to the waggons.

"Taking the cost at four and three-quarter lacs of rupees, we ought to consider that if there be a fair prospect of a return of 30 per cent., or 1,42,500 rupees in direct revenue, besides the benefits to be derived by the inhabitants, there is more than ample grounds to justify the construction of the works. One-third of this would be considered most abundant in England, and if it yielded only five per cent. or 23,750 rupees, it would pay the Indian interest of the cost; and the benefits obtained by the ryots would be a clear advantage.

"The results of the annicut may be properly divided into two heads, viz., *first*, the ultimate results; when by means of additional channels of irrigation, drainage, &c., &c., the water is led to the whole of the lands commanded by the annicut; and, *second*, the immediate results of the works now estimated for throwing water into the present channels, which will probably be realized to a great extent in the first year.

"*First.*—We are to examine into the probable ultimate effects of the annicut.

"It is evident that as the crown of that work will command the whole delta, there can be no possible reason why every acre of it should not be perfectly irrigated for one crop, that is, during the four months the freshes continue, and that all the best lands to the extent that the Godavery can supply water may be irrigated all the year round. We have, therefore, to consider the extent and present produce of these lands. The water from the annicut may, of course, be conveyed all the way to the Kistna, and it must necessarily affect all the country below the Colair lake; but it does not seem necessary here for me to go beyond the part of the delta lying in Rajahmundry.

"The following is a statement of the extent, revenue, &c., of these lands:—

DELTA.

	SQ. MILES.	ACRES.
Total extent of land in Rajahmundry	1,700 or	1,088,000
Deduct on account of sandy tracts, channels, roads, sites of villages, &c., quarter		272,000
Remaining cultivable land ... ... Acres		816,000
Or pooties at 8 acres to the pooty		102,000
Do. 10 do. do.		81,600

"The real measurement of the pooty is eight acres, but from the inquiries I have made, it seems certain that, on an average, the pooty, as entered in the village accounts, really contains about 1¼ pooty or 10 acres. I gather that the quantity of uncultivable land cannot exceed one-fourth of the whole, from the following returns of the contents of a large portion of the delta, taken from the village accounts:—

	POOTIES.
Gross extent of land	12,583
Cultivable land in the same village	9,878
Uncultivable land being about one-fifth of the whole	2,705

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" As no portion of the bed of the Godavery is included in these returns, the average of the whole of the delta to be deducted for waste must rather exceed the proportion of one-fifth, but can scarcely be so much as one-fourth.

The total permanent assessment on these lands is as follows :—

	RS.	RS.
Peshcush of the villages now in the hands of Zemindars and Proprietors	...	1,30,000
Peshcush of villages under Government management	4,37,000	
Permanent assessment of Government villages	7,23,000	
		11,60,000
Total ...		12,90,000 "

The report then goes into a consideration of the expected increase of produce and revenue, laying special stress on the probable cultivation of sugar-cane, which it was assumed would be much greater than has proved to be the case. The report then continues :

" We have thus, in a most palpable shape, a fair opening for an increase of revenue to the extent of 20 lacs, and of produce to the extent of 124 lacs, in the lands only that are in the hands of Government. If it be asked how is this great sum of money to be obtained, the answer is simply, by converting the water of the Godavery into money instead of letting it run into the sea. At this moment, water is paid for by the sugar growers at about one rupee for 800 cubic yards, the cost of raising it by picottahs. There are now about 420,000 cubic yards of water per hour flowing into the sea, worth, at the rate at which it is now actually and profitably purchased, 500 rupees per hour or 12,000 per day, which, for two hundred and forty days (the proportion of the year in which the district is not supplied at all) gives 28,80,000 rupees. This water, if applied to the land, would be worth to the cultivators full 50 lacs. The whole of this is at present lost. Through the remainder of the year, that is, during the cultivation of the great crop, about four times this quantity, or one and three-quarter million cubic yards per hour, are allowed to flow into the sea that might be profitably applied to the land, and in this way it may be understood by anybody how easily 100 lacs a year may be lost. That some such amount is actually lost, just for a want of proper care of the district, is shown in such a way that the conclusion is inevitable, by the actual state of Tanjore. The only question is, what expenditure is required to give us the full benefit of our natural advantage ? I have before estimated it roughly at 16½ lacs, and the further examination of the district that I have since made has given me a more favorable view of the case than I before had. It has several facilities that I had not calculated upon, especially in respect to the site of the annicut, which I thought would be 20 miles further up the river. The site now proposed, being at the head of the delta, will save the conveyance of the water for 20 miles, and the construction of an aqueduct to carry the water to the central tract.

" My rough estimate for the whole of the works required to put the delta in good order is now as follows :—

	LACS.
Present estimate for the annicut with its locks, sluices, &c.	5
Embankments to the river	1
Irrigation channels	2
Drainage works	1
Sluices, locks and other small works of masonry	1
Roads and bridges	2
Total ...	12

" This expenditure may appear as absurdly small, as the estimate of the capabilities of the district appear large ; but it is also very well supported by the

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case of Tanjore, if the circumstances of the two districts are considered. In my former report, I calculated the total expenditure on improvements in Tanjore at 16 lacs in forty years, during which time the revenue had risen 16 lacs; but here we have, in the first place, the prodigious advantages of the experience gained from all that has been done in Tanjore; and, *secondly*, what has been done there has been done piecemeal, while here we can make the improvements on one complete plan, which will make a very great difference. The cost of labour is also lower here, and materials are much cheaper. . . .

After further consideration of the probable returns from the works advocated, based on the actual results from similar works in the Tanjore and South Arcot districts, Major Cotton sums up and finishes his report thus :

"Upon the whole, therefore, we may consider the annicut as—

"*First.*—Laying the foundation for the complete irrigation, for a rice crop, of the whole Delta of the Godavery, and part of that of the Kistna, in all 3,000 square miles, or nearly 2,000,000 of acres.

"*Second.*—Providing for leading out on the land of every drop of water of the Godavery, in the low freshes, and thus making use of what is now totally lost.

"*Third.*—Opening the way for the conversion of the delta from a mere grain district to a sugar plantation.

"*Fourth.*—Thus the produce of this tract, which at present probably does not exceed 30 lacs, would, when full advantage is taken of the water thus distributed over it, be increased to at least 200 lacs.

"*Fifth.*—This tract which now pays with great difficulty about 22 lacs, would then, with great ease, pay 50 or 60 lacs.

"*Sixth.*—A complete system of internal navigation, intersecting the whole delta, would be established throughout the year.

"*Seventh.*—Every village would be furnished with a stream of pure water for the people and cattle at all seasons.

"*Eighth.*—The present estimate provides for the full irrigation of all the tracts at present partially irrigated by the principal channels of the Godavery.

"*Ninth.*—It will give us at once the use of a large portion (about one-third) of the water of the low freshes during the whole summer, thus providing for sugar cultivation to the extent of about 30,000 acres.

"*Tenth.*—It will give a constant supply of water to those tracts which, like Tanookoo talook, are situated near the present channels, but which receive no benefit from them at all.

"*Eleventh.*—It will put a famine in this or the neighbouring districts out of the range of probability.

"*Twelfth.*—It will provide immediately two or three most important lines of water communications from Rajahmundry through the heart of the delta to the sea, available at all seasons.

"*Thirteenth.*—It will have the important effect of showing to the people what can be done for them. At present they have no idea of the water being thrown into the channels during the summer; and from the first moment that water is seen passing through any villages in the low freshes, the whole people of the delta will be awakened to its great capabilities, and will be prepared to welcome the opening of channels throughout the whole tract, and to extend the cultivation of sugar and other things which are at present limited by the want of water.

"*Fourteenth.*—It may be estimated to yield one lac of rupees, or 20 per cent. on the outlay in the first year, and at least five lacs, or cent. per cent., within ten years. This is much less than the new works in Tanjore yielded under circumstances which did not offer anything like the advantages that the state and capabilities of this district hold out.

"*Fifteenth.*—But it seems to me that the most important point of all, in the present state of this district, is its capabilities as a sugar plantation; and the annicut will immediately provide for the most unlimited extension of that culture. When this work is executed, there will not remain a single obstacle to this most valuable plant becoming the main produce of this district. Water would be provided for at least 3,000 * pooties, producing with the Indian cane, sugar of the value of 1,300 rupees per pooty, and with Mauritius cane, if I am rightly informed, double that sum, while grain produce is worth only 120 rupees per pooty.

"Upon the whole, we have in this case almost everything that the most timid could desire to encourage us to prosecute the undertaking. On the one hand, the most perfect success and almost unprecedented results from precisely similar works in Tanjore; and, on the other, immediate returns for what has already been done in this district, more than ten times as great as would have been an ample return for the expenditure. Added to this, we have a product, which can be raised here probably at one-fourth the cost that it can be produced in the countries from which it is at present chiefly obtained. Both the culture and manufacture have been fully tried, and nothing is wanting but that the water which flows perpetually through the district should be applied to the lands; and this can be done at a cost which, compared with the object in view, is most insignificant. What this district may become, if this matter be taken in hand with only a small part of the energy it deserves, it is not easy to conceive. The unfailing river, an immense expanse of the richest soil, a safe and accessible port, a complete internal water communication with teak forests, a climate and soil perfectly suited for sugar, and abundance of labour at only 1½*d.* a day, form such a combination of advantages as I suppose cannot be found in the world, and certainly not under such a Government as ours. The climate being quite healthy, and free from excessive heat all along the sea board, also opens it fully to the establishment of sugar works under European superintendence. Its situation too, between the two great ports of Madras and Calcutta, makes it very convenient for commercial undertakings.

"I conclude this report without entering upon many points which might be considered, because it does not seem desirable to make it too long. I believe all the important points have been examined, and that much more than enough is stated to establish the importance of the proposed works. I do not attempt to answer the objections that will of course be started in this case, as there were when the Tanjore works were proposed; but I have fully satisfied myself that no objection can be preferred that has not been fully answered already by the results in that district, or which cannot be easily answered on sound grounds. So far as the objections to these works were made known to me, and I was allowed an opportunity to answer them, there was no difficulty in showing their futility. Those which were withheld from me, so that I could not refute them at the time, have since been answered by the works themselves.

"It will be evident that the future progress of this district depends above everything upon the means which may be provided for the sugar culture, and that it is hardly possible for the Government to take too decided measures for promoting this most valuable cultivation. The providing water is of course the first thing, but it is very possible that many minor means might be employed which would have an important influence in the matter. An ample supply of the Mauritius cane, which the ryots are anxious to substitute for the common kind, and which thrives well; the collection of the whole of the rent of the land after the crop is secured, or the substitution of custom duties at the place of exportation for the greater part of the rent, so as to diminish, as far as possible, the capital required for the culture, and free the ryots from the interference of the Government servants, and of the money-lenders; a lower assessment for the first year upon the lands cultivated with Mauritius cane—these are some of the means which would tend to forward the culture, if upon consideration they appeared to be admissible on other grounds. The subject deserves the most careful examination, and upon the means that may be used will depend in a great degree the rapidity with which the works now recommended will produce the results which they are calculated to yield.

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* 30,000 acres.

"I will only add the following remarks:—

"*First.*—With respect to the estimated cost of the works now proposed, viz., four and three-quarter lacs; that it provides for a solid and permanent work, and that the prices allowed are those at which such work can now be executed, without allowing for many reductions that may confidently be expected, if subordinate European superintendence is made use of. A sum of 30,000 rupees or six and-a-half per cent. is allowed for sundries and contingencies. If it should be considered that, in dealing with so large a river, this is not sufficient, any additional sum might be sanctioned, though I think we have no right to calculate upon contingencies which would require a larger percentage than this. Both the Colleroon annicuts, and I believe every one of the subordinate works of any consequence, were executed under the estimated amount.

"*Second.*—With respect to the estimated returns, I have given a statement of the lands, their present collected revenue, the permanent assessment, &c., from which any persons may form their own judgment of the probable effects of these works. I think they must fully support my expectation that they will yield 100 per cent. on the outlay; and this is also abundantly supported by the actual returns in Tanjore, which have already much exceeded that percentage, though under circumstances much less favourable than those of Rajahmundry.

"*Third.*—The sum for which sanction is now requested, being the cost of the annicut, and subordinate works for keeping the present channels supplied, is four and three-quarter lacs. The remaining works necessary for the completion of the irrigation, navigation, embanking, and roads of the delta within Rajahmundry, are roughly estimated at seven lacs. This does not include the detailed works that would be required in the Masulipatam district, if it should be determined to extend the channels as far as the Kistna. If this further tract of country should be in the same manner provided with such works, I have no doubt that returns little short of 100 per cent. would be obtained there also.

"*Fourth.*—I need hardly observe that if this work is undertaken, it will be necessary to have it executed in the manner in which large Military buildings are constructed, that is, under the entire control of the Engineer Officer. This is especially necessary in the northern districts, as the Native revenue authorities have no experience in such works, and it is almost impossible to get even a common sluice built in a whole season under the ordinary system, from the utter inefficiency of the people in respect of works of Civil Engineering.

"I think there can be no objection made to my earnestly requesting, in the conclusion of this report, that the objections that will be made to every part of the project may be openly discussed, and that not one will be allowed to be said or insinuated, but what shall be put on paper, and the fullest opportunity allowed to me of answering it. It seems to me that, in justice, the least that can be granted to any one who takes upon himself the great responsibility of proposing and urging extensive improvements of this sort, is that he should be allowed to defend his project against the objections of others; when it is considered how many difficulties will appear, even to the unbiassed, who are not conversant with such subjects, but for which any professional person will know that there is not the slightest foundation."

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The Collector of the district, Mr. T. Prendergast, was then called on by Government to give his opinion as to Major Cotton's proposals, and did so in a letter, dated 26th February 1846, which concluded thus :

"39. In the above remarks I have purposely avoided a critical contrast between Major Cotton's figured statements and those deduced from my official records, because as I mentioned early in this letter, the former are avowedly given with less attention to accuracy of detail than would be expected from the Collector's Office, and I have been unwilling in any way to lessen the warmth of the support I am desirous of giving to the project, by constantly recurring to minute differences, which are after all of no consequence to the general question.

"40. Two facts are undeniable, one that the Delta of Rajahmundry, rich and fertile as its soil may become with the assistance of water, is comparatively poor and barren; the other, that the Godavery bears annually to the sea the means of fertilizing the whole country. With the scientific question of the erection, stability, and cost of the work, I have no concern, but what has been done once may be done again, and the Colleroon Annicut stands as a model, an encouragement, and a guide in the present undertaking."

The Chief Engineer, Lieutenant-Colonel A. Lawe, also advocated the execution of the project, and the Board of Revenue sent it on to Government with a long letter, dated 9th April 1846, from which the following are extracts :—

"18. The Collector's accounts of the area of the delta differ considerably from the estimate (derived from the map) of Major Cotton; but their several statements of culturable lands more approximate, the difference between them being only from 40,000 to 50,000 acres, if the pooty is taken at the measurement of 10 acres. As long as the actual value of the pooty in acres is a matter of question, it is impossible to arrive at a just conclusion on this subject. It is however sufficient for the purposes of this report to assume as true the lowest estimate of the culturable lands, namely, 616,000 acres, which, if brought under the influence of the annicut, would immeasurably repay the cost of all the works. . . . .

	Pooties.
District accounts of delta land ...	91,284
Deduct unfit for cultivation ...	14,381
Remain ...	76,903

Pooties at 8 acres 615,216 acres.

"50. It may therefore be very reasonably expected that in Rajahmundry, where there is so fair and clear an opening for the introduction of a most valuable agricultural product, a perfect system of irrigation may be established with great success, and that there will never be cause for alarm in the production of what is unsaleable with profit. Yet even were the prospect unfavourable in this respect, the reality never could approach in importance to that of a general famine, aggravated by the neglect of the great sources of irrigation. In this light alone the construction of irrigation works in those districts, where the supply of water is almost always certain and abundant, seems to be imperatively required by a sound policy. . . . .

"55. The Godavery itself will require a considerable annual outlay, but it does so now, and to its not having received its due, must be ascribed the disastrous effects of floods, which alone have caused immense loss in Rajahmundry. . . . .

"57. The estimates of Major Cotton appear to provide amply for all the proposed work; and the Board, trusting that they may receive the full approval and support of the Most Noble the Governor in Council, direct me to solicit sanction for the amount thereof, viz., Rs. (4,75,572) four lacs seventy-five thousand five hundred and seventy-two.

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"58. It is most desirable, the Board finally observe, that if the project be finally approved, authority should be granted for the commencement of the work early next year."

The Government of Madras dealt with the matter in its 'Minutes of Consultation,' dated 1st September 1846, and resolved "to bring the correspondence on the subject of the projected undertaking to the notice of the Honourable the Court of Directors, with the strong recommendation of this Government that sanction be granted for the disbursement of the estimated amount, viz., Rs. 4,75,572, and that their orders be communicated in time for the commencement of the work at the beginning of the ensuing year."

The sanction of the Court of Directors was communicated in the following despatch :—*

No. 19 of 1846.

OUR GOVERNOR IN COUNCIL AT FORT St GEORGE.

"1. With your letter, dated the 1st September last, No. 41, you have transmitted for our favourable consideration a proposal for improving the irrigation of the Rajahmundry district by the construction of an anicut across the Gódávari river, and you have solicited that our orders may be communicated to you in time for the commencement of the work at the beginning of the ensuing year.

"2. The district of Rajahmundry, although highly favoured by nature both in the quality of the soil and in the means of artificial irrigation, has been hitherto almost entirely neglected. The rice cultivation, which furnishes the principal subsistence of the inhabitants, has been allowed to depend on the precarious rains of the monsoon, so that seasons of scarcity, and even of famine, have been of not unfrequent occurrence, while the never-failing waters of the Gódávari have been permitted to flow in useless abundance to the sea.

"3. The investigations of Major Cotton, the Civil Engineer of the division, as detailed in his able and interesting report of the 17th April 1845, have shown the practicability of turning the waters of that river to the most profitable account by the construction of an anicut of such a height as to command the whole of the Delta of the Gódávari and to supply to the rich alluvial soil of which that tract is composed, the means of constant irrigation.

"4. The work, which would be of a similar character to those already constructed in Tanjore, although considerably more extensive, appears to present fewer natural difficulties, and in the immediate neighbourhood of the spot, abundance of stone fitted for building and for the manufacture of lime is to be found. The cost is estimated by Major Cotton at Rs. 4,75,752, although he is at the same time of opinion that the actual outlay will fall somewhat below this sum.

"5. The advantages which the undertaking is calculated to secure are variously estimated by the Civil Engineer and the Collector, Mr. Prendergast; but at the lowest amount which the Board of Public Works have considered it reasonable to assume, the total cost with compound interest at five per cent., together with the expense of repairs, will be recovered in the course of ten years, and a clear profit of at least Rs. 90,000 per annum will be in future yielded to Government.

"6. The Civil Engineer dwells at much length on the peculiar facilities which would be found in this district for the cultivation of sugar, provided the means of constant irrigation were secured, and the Collector states that the experiment has already been tried on a limited scale with considerable success.

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* Received early in 1847.

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"7. Major Cotton's experience in the construction and results of similar works in Tanjore adds great weight to his opinion on this subject. We are, therefore, willing to rely on his representations, which so far as regards the feasibility of the undertaking, have received the unqualified approval of the professional member of the Board of Public Works, Lieutenant-Colonel Lawe, the Chief Engineer, who has recorded a separate minute on the plan; and with respect to the high importance of the work, the Board of Revenue and the Collector entirely concur in opinion.

"8. We accordingly comply with your strong recommendation in favour of the project and sanction the proposed expenditure of Rs. 4,75,752 for carrying it into execution."

We are,
Your loving friends,
(Signed) J. W. Hogg.
(,,) H. St G. Tucker.
(,,) H. W. Sykes.
(,,) W. L. Melville.
(,,) W. H. C. Plowden.
(,,) E. Macnaghten.
(,,) John C. Whiteman.
(,,) Robert Campbell.
(,,) Hy Alexander.
(,,) Archd Robertson.
(,,) Henry Willock.
(,,) M. P. Smith.
(,,) F. Warden.

London,
23*rd December* 1846.

The sanction thus given was for the Anicut and masonry works immediately connected with it, *plus* a small amount of Rs. 14,000 for "the partial clearing of the present channels." When sending in the estimate for Rs. 4,75,572 for these works Major Cotton stated (see page 21) that a further expenditure would be necessary "for the whole works required to put the delta in good order," which would raise the cost to 12 * lakhs, a sum which he truly said might "appear as absurdly small"; that it actually proved so will be seen hereafter.

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* Twelve lakhs in Major Cotton's 'second report' of 17th April 1845, but in his 'first report,' 12th August 1844, he had put the amount at 16½ lakhs.

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CHAPTER III.

GÓDÁVARI ANICUT—SITE AND DESIGN.

Before proceeding to an account of the execution of the works, it will be advisable to give a brief description of the site and design for the Anicut.

Site of Anicut.

As already stated, Major Cotton finally decided to build the Anicut at the head of the delta, just below the village of Dowlaishweram. The breadth of the Gódávari at the place is, from bank to bank, rather over 3$\frac{4}{5}$ miles; but of this more than a third is occupied by three islands and the head of the 'Central Delta,' which separate the river into four channels, and are thus disposed. At about a mile from the eastern or left bank of the river, is the island known as 'Pichika-lanka*' some 2,300 feet broad; it is about 4 miles long, and the branches flowing on either side of it are known as the 'Dowlaishweram' and 'Ralli' branches respectively; they unite at the lower end of the island into one stream, the 'Gautami Gódávari.' On the west side of the Ralli branch comes the head of the 'Central Delta,' known as 'Bobber-lanka,' which is about 1,400 feet across before the 'Maddúr' branch is reached; this, the narrowest of the four branches, is separated from the next, the 'Vizéswaram' branch, by the 'Maddúr-lanka' nearly 1,900 feet wide. This island extends but a short distance down stream, and below it the Maddúr and Vizéswaram branches unite in the 'Vasishta Gódávari.' To the west of the Vizéswaram branch comes the 'Chigaru-lanka,' 1,830 feet wide, separated from the main land by the narrow channel in which stand the 'Scouring' or 'Under' sluices of this flank of the anicut.

The river bed was of pure sand and the islands merely thin alluvial deposits over it; whilst floods upwards of 25 feet in depth swept 1$\frac{1}{2}$ millions of cubic feet of water per second past the place. The problem, therefore, which Major Cotton had before him, of how at such a site to deal with the river and so bring it under control, that even in its low stages it would be made to command almost all the deltaic lands, was no easy one. He decided to solve it by building a masonry dam, or 'Anicut,' 12 feet high, upwards of 2$\frac{1}{4}$ † miles long, across the river bed, with embankments on the island of a total length of 7,365 feet.

The execution of the proposed work would, he saw, be facilitated by the great regularity of the Indian seasons which assured with almost absolute certainty a 'working season' of some six months in each year, during which the discharge of the river would be no greater than could be diverted to any one or two of the branches, so that in the others work could go on untroubled by surface water. But the project was a bold one. The proposed work was

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* 'Lanka' = island.

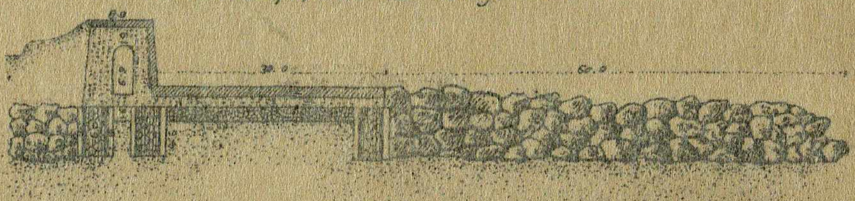
† Actual length of anicut as built, *exclusive* of Under sluices and wings—

	FEET.
Dowlaishweram branch	4,940
Ralli branch	2,859
Maddúr branch	1,548
Vizéswaram branch	2,598
Total ...	11,945

Facsimile of drawing facing page 58 of Vol. III Professional papers—Madras Engineers.

PROPOSED SECTIONS of the GODAVERY ANNICUT

Section first proposed for the Godavery Annicut



Revised Section proposed for the Godavery Annicut

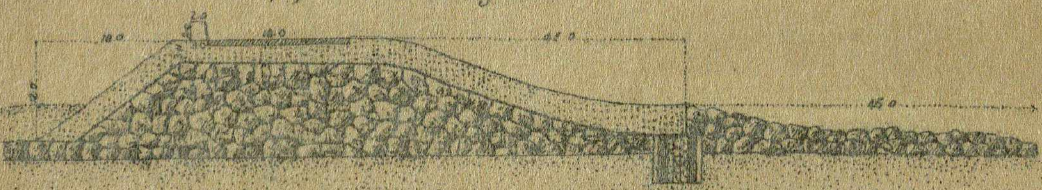


Photo-zinco., Survey Office, Madras.
1895

without a prototype, except the anicut on a much smaller scale which Major Cotton himself had built in the Tanjore district, and it was to be carried out, where no engineering works of any size had ever been constructed, by means of rude native labour and with apparatus which was generally of quite a primitive description. The greatness of the task, and the difficulties which surrounded its execution, in no way daunted Major Cotton; he never, for a moment, entertained the slightest misgiving as to the success of his scheme.

Designs for the Anicut, original, modified, and final.

Major Cotton's original design for the anicut had a narrow crest with a vertical drop on to a cut-stone floor, the section being very similar to that of his 'Upper Anicut' on the Coleroon. Before commencing work, however, he altered the design to a very different one with a broad crest and sloping apron. The original and revised sections are shown on the plate facing this page, and Major Cotton's reasons for the change are given in the following letter, which he sent to the Board of Revenue on 17th February 1847:—

"Since I sent in my plans and estimate * for the Godavery annicut, and especially since I have commenced quarrying at this place, I have been much employed in comparing the expense and difficulty that may be expected in procuring and applying the different kinds of materials that may be used in constructing this work. The question was what mode of construction consistent with security would be most suitable to our circumstances, as respects cheapness and facility of execution, considering the nature of the materials procurable and the resources of the district as regards workmen.

"I would now beg to submit for the Board's consideration the following modification of my former plan.

"I find that the great quantity of cut-stone there proposed, will require so many more masons than the district can supply, so as to complete the work within a moderate time, that it would be very desirable, if possible, to give the work a form that would require less of this material. The facility of construction, involving the question of time is, next to security, the most important point. The delay of a year would no doubt cause a loss of one or two lacs of rupees, and much more some years hence. I find from my late trials in the quarry that it would probably take about 1,000 stone-hewers and stone-cutters to prepare the requisite quantity of cut-stone in two years, and from what I have yet been able to learn, I am afraid that nothing like this number could be procured; the section I now forward, therefore, is such as, by avoiding an overfall, excepting where the under-sluices occur, will admit of the principal part of the surface of the work being made of rubble work pointed with concrete and finished with a surface of smoothed chunam, such as the sluices and other works are finished with in Tanjore, when not lined or covered with cut-stone. The principal part of the work will thus consist of loose stone, of which there is an unbounded supply, the greater part ready broken, and which can be brought to the work very rapidly by rail-roads.

"This is the mode of construction originally used at the ancient native work called the Grand annicut,† which has stood for so many centuries. Part of it has indeed been raised and covered with cut-stone, but a few years ago part of it was still without that protection. On cutting through the work to make the under sluices, the mass was found to consist of nothing but loose stone in mud, with the upper course only laid in chunam, and plastered with concrete. It has never required anything more than occasional renewals of the concrete, and has never been in any danger, or given cause of alarms.

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* Amounting to Rs. 3,41,373-3-0.

† A large weir in the left bank of the River Cauvery

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"Here, where material is abundant on the spot, and skilled labour scanty, it is worth considering whether such a rude mode of construction may not be adopted with advantage. In my first report on the Godavery I proposed this kind of work; but I afterwards thought the employment of so vast a mass of materials would involve more delay than a more scientific construction. Since I sent in that report, I have had much more opportunity of investigating the subject, and my main objection to the use of rude materials has been removed. I find that round timber, straight, hard and durable, and perfectly suited for rails without sawing, can be obtained in great quantities at a most trifling cost. Such timber, from six to seven inches diameter, and 20 feet long, is procurable at from 20 to 25 rupees per 100 logs; so that sufficient for a mile of single railway, including cross pieces, that is 20,000 feet lineal, will cost from 200 to 250 rupees. Such rails adzed to a level on the surface, with flat two-inch iron screwed down upon it makes an excellent temporary rail-road at so moderate a cost, that any length of it may be laid without an excessive expenditure; and by thus having several lines of railway, a great mass of materials may be conveyed in a short time without confusion.

"The proportional cost of the materials which may be used in the work, so far as I have now been able to ascertain them, will be as follows:—

	RS.	A.	P.
Loose rough-stone, per cubic yard	0	1	0
Rubble stone in chunam, per cubic yard	0	12	0
Brick in chunam	1	2	0
Cut-stone in chunam	4	0	0

"From this it will be seen that, as respects cost, 18 cubic yards of loose stone may be executed at the same expense as one of brick in chunam, and 64 at that of one of cut-stone in chunam. These prices include everything but superintendence and the cost of the rail-roads. From this it may be judged that, so far as loose stone can be substituted for regular masonry, a considerable saving may be effected. And, upon the whole, I think that there would be a difference in favour of the mode now proposed of full 80,000 rupees. But, as I have said, I consider that even as respects pecuniary results, time is of more consequence than expenditure; that is, that the loss of a year would more than counterbalance any saving we could make in the execution.*

"The section which I have the honour to forward, shows the construction I now propose; but I should observe that I would adopt this only to the extent that appears necessary as the work proceeds. Thus, if I should find that it would be delayed by our not being able to begin the western divisions of the annicut till the railway was completed across the river, I would prefer constructing one or both of these divisions of brick and cut-stone rather than lose time.

"The section shows, however, another material alteration that I propose; and this is, to give the whole work a breadth of 18 feet in the clear at the top, so as to provide both an ample road-way during the time that the river is low, that is, during eight months in the year, and also to allow of a bridge being carried along it without altering the original work. It seems to me that, if this can be accomplished without exceeding the estimate, a very important point will be gained. To make the annicut fully answer the purpose of a bridge, while the river is low, I propose also to make the broad surface of the annicut two feet lower than the crown of the work; building a wall, two feet high on the upper side, to keep the road-way dry and prevent accidents. It is to be observed that, as the under sluices will be of great capacity, they will discharge a large body of water, so that none will go over the work excepting while the freshes are high; and as during that time there is but little traffick in the country, the annicut will thus almost answer the whole purpose of a bridge.

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* "The plan now proposed will, however, as I expect, save both time and money."

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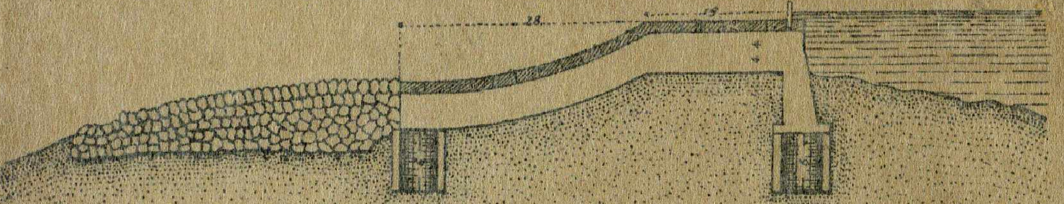
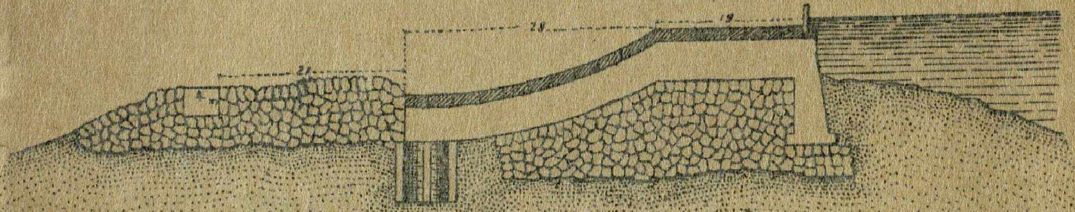
Facsimile of drawing facing page 186 of Vol. III Professional papers—Madras Engineers.

SECTIONS of GODAVERY ANNICUT as COMPLETED.

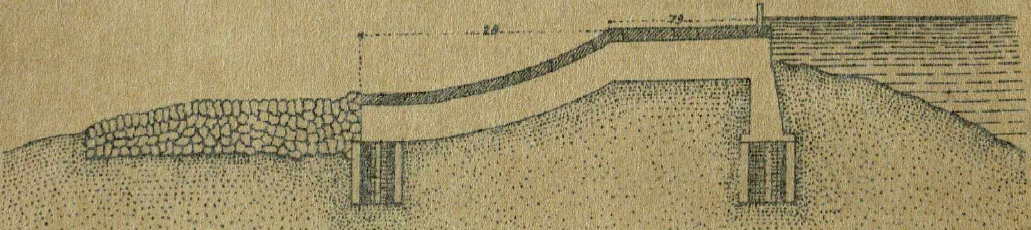
Section across the Dowlaishwarum Firkah (or Division)



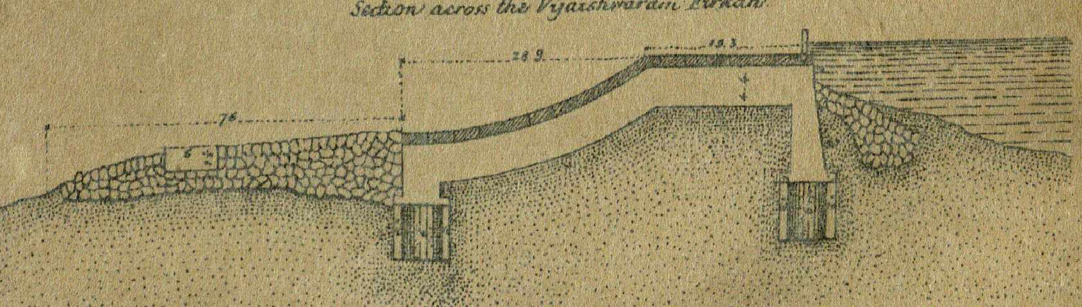
Section across the Ralee Firkah



Section across the Muddoor Firkah



Section across the Vyjaishwaram Firkah



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GSL

"So far as I have been able to ascertain from the additional data I have obtained, especially from the extensive buildings just executed near this spot, for the manufacture of sugar, and from the quarrying already performed, I am happy to state that the rates allowed in my estimate for each kind of work exceed those at which they may severally be executed; so that unless the contingencies are much beyond my expectations, there is every prospect of the work being completed within the estimate, independently of the cheaper mode of construction now proposed, and including the additional breadth allowed for the top of the work.

"In so extensive a work, in a situation where nothing of the kind has hitherto been executed, it is not to be supposed, but that some additional information may be obtained, and some improvements may be thought of, the longer the subject is under consideration; and as I cannot but hope that even yet, as we proceed, some useful though not essential changes may suggest themselves, I would respectfully request that I may be allowed to make them, keeping the Board informed of anything I propose that is at all of consequence.

"An estimate of the cost of the section now proposed, *at the prices originally estimated* (excepting allowing for the lower cost of the railways), is forwarded, for the purpose of comparing the expense of it with that of the former section.

"The various preparatory works will now be pushed on as fast as possible, in order to be well prepared against the cessation of the monsoon permits us to commence upon the main operations."

But even the revised design was considerably departed from in construction, and the actual form the work assumed will be seen on the plate which faces this page, and the 'Sections of the Anicut' in the Atlas volume. The change in design deserves some consideration.

In a river, such as the Gódávari, with an unstable bed, the action of the water which passes over a dam is, when there is considerable difference of level between the upper and lower reaches, of the utmost importance. With a dam such as in Major Cotton's first design, the disturbance caused by the impact of the falling water is very violent, but it takes place near the body wall and expends itself in a short distance from it. With a sloping rear apron starting from, or just below, the crest of the dam, as in the design finally adopted, the water rushes down the slope and is delivered at the lower level with an action which, though it does not immediately set up such violent disturbance as in the case of a vertical overfall, throws the lower reach into a state of agitation, with reverse under currents, for a much greater distance from the work. A more extended protection to the bed below the work therefore becomes necessary. This necessity soon became apparent at the Gódávari Anicut, and in 1852 we find Colonel Cotton writing thus: "In fact[*] the quantity of rough-stone below the work throughout very far exceeds what I contemplated; and I think it will be advisable to continue to throw in 20,000 tons a year for some years to come." From the sections of the work given in the Atlas volume, it will be seen how extensive are the additions which have had to be made to the rough-stone talus; its width has now become from three to six times that anticipated, whilst its thickness has been greatly increased by the enormous quantities of stone thrown in to make good the sinkage which has, from time to time, taken place. Those quantities amounted in the first twenty years of the anicut's existence to 290,029 cubic yards, or, say, 507,000 tons; the subsequent records on the subject are not complete; they show however that since then *more* than 200,000 cubic yards, or 350,000 tons, have been thrown in, and there can be little doubt that one million tons of stone in addition to that used when constructing the anicut, have had to be deposited below it to secure its safety.

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[*] Letter No. 29, dated 29th January 1852.

Even now, notwithstanding the great breadth and thickness of the talus, it requires constant attention; parts of it not infrequently sink considerably, and holes are scoured out below it, which, in the experience of the writer, have attained a depth of 60 feet, necessitating further extensive additions of stone. A practically unlimited supply of stone available within moderate distance of the work is therefore a *sine quâ non* in the adoption of such a design as that finally decided on for the Gódávari Anicut, and the work had scarcely been finished when Colonel Cotton wrote thus:

> "I must,* however, say, that here as in the Colleroon, I would now prefer building a work with a vertical fall, as safer in a sandy river; and so I would in any place excepting one similar to the Kistnah, where there is an unlimited supply of stone at very low rates, and where consequently 20 cubic yards of rough-stone could be obtained at the same cost as one of cut-stone. When I planned the Colleroon Annicut, I considered that the great point in these rivers was to break the force of the water effectually, and prevent it scouring the lower channel; and what I have here seen makes me think still more of the importance of that principle. But I believe, where stone can be obtained very cheaply, a large mass of rough-stone, with a very long slope on the lower side, will be the cheapest and safest work in a sandy river."

Fortunately the supply of stone available near Dowlaishweram, as at the Kistna Anicut, has proved to be practically unlimited.

But the immensely increased protection below the dam is not the only considerable difference between the adopted design and the executed work; there is another of great interest. The Plate of 'Proposed Sections of the Gódávari Anicut' opposite page 29, and Major Cotton's letter No. 26, dated 17th February 1847 (*see* same page) show that it was intended that the dam should rest on a mass of loosely deposited stone, but from the 'Sections of the Anicut' as actually carried out, in the Atlas volume, it will be seen that, except across a portion of the Ralli branch, no such mass of stone was used, and that the work rests on sand confined between the foundations of the front wall and those of the curtain wall at the toe of the sloping apron. With reference to this, Major Cotton says in his letter No. 111, dated 14th April 1852, above quoted from:

> "The Rallee branch is where the great breaches occurred repeatedly in the first rough-stone dams thrown across, to retain the water for navigation in the bed of the river. Where these breaches occurred, holes were cut by the water from 20 to 30 feet deep, which were again filled with loose-stone. It is very remarkable that this is the only part of the foundations that has caused any trouble. Where the work rested on sand it stood well; but these deep rough-stone foundations allow the water to pass through in large quantities; and repeatedly we have found, from moisture appearing in the joints of the masonry, and from heavy jets of water, a foot or more high, appearing through the rough-stone apron, that the water was pressing against the under side of the masonry of the annicut; though from its great thickness in its finished state, it can resist the pressure effectually. When first this branch was built, the rough-stone which had been thrown into the breaches was not carried up to the point where the solid masonry commenced; but it was covered with some feet of sand washed in with water, and the masonry laid on that. It is to be observed, that the masonry of all the rest of the annicut is laid on sand between the front and rear retaining

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* Report No. 111, dated 14th April 1852, to the Board of Revenue.

walls; but in other parts it cannot be washed away. Here the water passed through the stones under the front-wall, and carried the sand under the masonry away. The consequence of this was, that the masonry in these places cracked, and in one spot sank till it rested on the rough-stone. When the work was examined, it was found to be hollow underneath for a considerable distance. This is very instructive. There is no better foundation for masonry than sand, if it is secured from currents of water; it is indestructible and incompressible, and so far is just as good as rock; but in situations where currents of water can get at it, as it is not like rock, immovable, it is the worst of all foundations."

Over and over again has the truth of these observations been proved in the execution of the Delta works, and where any of them have cracked or settled unequally, it has almost always been when founded, *not* on sand, but on so-called 'clay.' There have however been failures of works built on sand owing to insufficient protection of the foundations 'from currents of water' and especially from that most dangerous of currents, the eddy. An important instance of this will be given in the account of the destruction of the Head sluice of the Central delta.

From the extract given on page 19 from Major Cotton's 'Second Report,' it will be seen that, in the estimate sanctioned by the Court of Directors, the following works in immediate connection with the Anicut were provided for, viz., six sets of Under Sluices, five Locks, and two Head Sluices. These arrangements were afterwards modified thus. Only three sets of Under sluices of 15 vents each were built; one near the Head sluice of each of the Main canals of the three Sections of the Delta; only three Locks were built; one at the head of each of those canals; the two Locks intended to pass river navigation round the flanks of the anicut being given up, because it was evident that, when navigable canals were carried to tide water, there would be no necessity for using the precarious and dangerous river navigation below the anicut. Instead of only two Head sluices, one for the Western and one for the Central Sections of the delta, as originally provided, a third had to be added for the Eastern Section; why it was not contemplated from the first is not clear, but in 1848 Colonel Cotton stated that an estimate for Rs. 8,000 was being prepared for this 'third head sluice.'

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CHAPTER IV.

GÓDÁVARI ANICUT AND HEAD WORKS—EXECUTION FROM COMMENCEMENT, TO END OF 1851-52.

As already stated in Chapter II, the sanction of the Court of Directors was received early in 1847, and no time was lost in commencing operations; little, however, could be undertaken in the way of actual construction in the bed of the river before the flood season of that year. In his letter No. 190, dated 18th August 1847, to the Board of Revenue, Major Cotton thus stated what had up to that time been done:

"As soon as the annicut was sanctioned, the following works were commenced, viz. :—

The preparation * of more boats.
The erection of buildings for workshops, for the stores, and for sheltering the people, &c.
The construction of lime kilns.
The embankment across the islands between the wing-walls of the annicut.
The cutting of the new heads to the channels.
The preparation of bricks.
The more complete opening of the quarry, with rail-roads, &c., and cutting stone.

"The Sub-Collector also commenced the preparation of firewood and charcoal in various parts of the district.

"At first, only a few hundred people assembled, but by the arrangements of the Sub-Collector, about 4,000 were collected in a short time, and after a few weeks they began to come in considerable numbers, amounting to 10,000, before the setting in of the monsoon called them away to cultivation. The numbers have since fallen to about 3,000 employed at this place.

"When some extent of shelter had been prepared, and a few lacs of bricks were made, the sinking of wells for the foundation of the annicut was commenced and continued till the rise of the river in July stopped this part of the operations. A second line of rail-road was afterwards begun, leading from the quarry to the river above the village of Dowlaisweram. This is intended to convey stone to the boats, to be conveyed across the river and deposited near the wing-walls of each division of the work, to enable us to commence at all parts of the work at once, and that we may not be compelled to wait for the railway communication across the river to be completed, before we can have stone for use at the opposite end of the annicut.

"The state of the works at present is as follows :—

"The quarry has been nearly opened enough; but there is still not sufficient length of face exposed to enable so large a number of stone-cutters to work. The rail-roads in the quarry are also incomplete, from want of iron, an additional quantity of which, however, has now arrived.

"The rail-roads from the quarry to the river are also nearly completed, but have also been delayed from want of iron.

"Almost all the necessary buildings have been completed; viz., workshops, chunam sheds, a hospital, hutting for about 500 artificers and 4,000 coolies, &c.

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* Two had already been began on some preliminary sanction.

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"The minor apparatus required in the workshop is nearly completed. The embankments across two of the islands have been completed. The new head for the Eastern main channel has been opened, and a large embankment thrown across the old head; the Central and Western main channels have been excavated to a great extent. Ten boats of 25 tons each have been launched, and eight are now in use: eight more are nearly ready. Eleven railway wagons are in use, and several more are nearly ready. Timber rails sufficient to complete the two double lines of railway from the quarry to the river, and half those required for the railway from the lime-stone quarry to the river, above Rajahmundry, have been fitted; in all six and-a-half miles of single railway. Iron has now arrived sufficient for these lines, so that I hope before the great fresh of September is over, we shall have two double lines of railway finished, with 50 wagons to carry 4 tons each, and 20 boats of 25 tons each.

"The statement of expenditure will show the extent of work executed.

"Upon the whole I think we must consider the works to have gone on well, considering our circumstances. Our principal difficulty has been, and is, the keeping the people to their work: there has been very considerable waste in some part of the operations, especially in the embankment, from their idling; it being almost impossible to find a peon who is not more idle than the men he is superintending. But as this has arisen mainly from the great numbers of people employed before we had sufficient superintendence, and from things being at first in disorder, compared with the state we may hope to get them into after a time, we may hope that in this respect also there will be nothing to complain of, particularly with the additional European superintendence that we shall now have.

"That we have made the progress that we have is entirely owing, under God, to the Sub-Collector, whose vigorous and active measures have already roused the district to a degree that could not have been expected; and it may be said indeed that, as respects the getting public and private improvements effected, the district is ten years in advance of what it was a few months ago. The people have come freely from all parts of the district, and both they and the Native public servants now fully understand that great improvements can be effected. The actual use of the Godavery water from the new channel as far as Samulcottah, over an entirely new tract of country, has also no doubt helped to enable the people to realize the practicability of improving the state of the district.

"With respect to the estimate, as we have not yet trenched upon some of the largest items, I cannot speak confidently; but so far as we have gone, I think there has been a fair result for the money expended.

"It will be seen from the detailed estimate contained in the statement now forwarded, that about one and-a-half lacs of rupees will be laid out in railways, boats, buildings, machinery, &c., all which will be of value when the work is done, and will be of use in the execution of the remaining works included in the estimate of 12 lacs."

On the 23rd October of the same year, he further reported:

"During the three monsoon months we have necessarily limited our operations chiefly to the quarry, the construction of the railways, the preparation of apparatus, and the burning of chunam.

"3. The quarry has been greatly extended, and railways carried through most part of it, though the length of the rock laid open is still rather too confined for the number of stone-cutters employed. But having now four cranes and about 16 wagons at work, the further opening of the quarry will proceed rapidly. One double railway is completed from the quarry to the river, and has been in use for some time. The wagons run the whole way of themselves, the road having a good slope. At present they are discharged on the side of the road, and the stones carried into the boats, which come up close to the end of the rails; but a wharf will soon be completed to enable all the small stones to be discharged into

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the boats at once. The other double railway is now within a short distance of the river, and materials for it are carried from the quarries by the wagons. Eighteen boats have been launched, and they answer very well. They are chiefly employed in carrying stone across the river, and it is at present deposited near the sites of the head sluices and locks, for which it will be first wanted. About 150 tons a day are carried by water at present. On both lines of railway about 400 tons a day of stones and gravel are conveyed, and this quantity will rapidly increase. At least 50,000 tons of rough-stone have been quarried and thrown in heaps near the railways in the quarry, and about 8,000 tons have been conveyed to the line of the annicut. Cut-stone to the extent of 25,000 cubic yards has been prepared. Two kilns have been kept burning for about two months, yielding now about 200 parahs* of chunam a day each, and about 400 garce are now in store. The cutting and embanking for the railway from the limestone quarry to the river has been nearly completed, and a considerable part of the rails laid. It is two miles in length.

" 4. At one time, when the first fresh was rising, some alarm was caused by the current cutting away the narrow point of land that divides the head of the channel on the Dowlaisweram side from the river, but it was protected by some stones and no harm was done.

" 5. The new embankments between the wing-walls of the annicut, across Rallee and Muddoor Lunka, have stood excellently, having suffered neither from the rains nor the freshes. The water during the freshes flowed down the new cutting made on the Vijaiswaram side for the head of the main channel, and this has thus been of considerable use this year. The cutting in Rallee head has not been carried for enough to communicate with any of the old channels.

" 6. We are thus in a very fair position for commencing the operations of the season as early as the rains and freshes have permitted, and I hope very soon to be depositing 1,000 tons of rough-stone a day in the line of the work. We shall also shortly commence upon the head sluices and locks. We have had from 2,500 to 3,500 people at work during the monsoon, and they have already begun to come in again in considerable numbers. I have every reason to believe they will come in greater numbers than we can employ, unless we undertake a large quantity of earthwork this year; for we shall not require above 5,000 people at the annicut, now that we have got the principal railways in operation, and all the preparatory works executed.

" 7. With respect to the progress of the work, I have great reason to be satisfied, though we have been much delayed from want of artificers in metals, which has kept us back in the preparation of wagons and other apparatus."

In the 'Working season' of 1848, the work was pushed on with, and Major Cotton at one time hoped before the first freshes "to complete the whole four divisions of solid masonry." This very sanguine forecast he however soon modified, and in March of that year we find him writing:

"We have met with so many disappointments and causes of delay hitherto that I have been lately in great anxiety and doubt whether I could get the annicut into a safe state before the freshes; but I am happy to be able now to state that, under the following arrangement, there is every prospect of our getting through what seems absolutely necessary. I propose to complete all the wing-walls, sluices and locks, and to build two divisions of the annicut (or rather more than half the length of it) with solid rubble masonry to the height of nine feet above the deep bed, that is, three feet below the full height, and to make a broad dam of loose stones of the same height for the other two divisions, securing them well at the wing-walls by abundance of stones. As the overfall, with this height of dam, will be very trifling, I feel very confident that it will receive no injury of

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* Parah = 4,000 cubic inches or 1·8 bushels. Garce = 60 parahs.

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consequence this year; but should it be breached, I do not apprehend that there would, even then, be any serious mischief done; as with so moderate a head of water, if it did cut through the dam, the breach would not extend far, and the cost of repairing it afterwards would be trifling."

At the beginning of June he reported:

"On this (Dowlaisweram) side of the river, the masonry dam will be completed to the height of three feet below the ultimate intended height in two or three days. The lock will be completed to within 12 feet of the flood level by the end of next week, and it will soon be ready to receive its gates. Probably we shall be able to raise one pair of gates this year, but they will only be wanted for a few days, just to keep out the water in a full fresh: afterwards there will be so little head of water that the lock may be left entirely open. The head sluice is very nearly finished, excepting that the great arches are not turned; and I should prefer a lattice bridge over it, unless the rubble masonry, of which the piers are built, has a great deal of time to harden. We have been compelled to use this material from want of time; and there is no objection to it if a timber bridge is used, or if the masonry has time to set before arches are turned. The under sluices are in a safe state, but the progress of cut-stone work is so extremely slow (owing to the paucity and unskilfulness of the workmen) that it will be necessary to leave them open at the top this season: I do not apprehend any injury to the work from this circumstance. I should not have used cut-stone to the extent I have done in this work, had I thought it would have taken such enormous time; and in future I think I would never recommend its use in this district, excepting where other material could not be substituted, but would everywhere substitute partially fitted stone, which with this strong chunam would answer most purposes. The works at Rallee are in a more backward state. The under sluices will be, I hope, in a safe state in a fortnight; and they will be carried high enough for us to work at them as soon as the river falls 15 or 16 feet. They must be left open like those at Dowalisweram. The lock has been begun; but it must be given up for this season, and indeed it was a mistake to begin it, as the channel will take long to cut. The head sluice is well advanced, but it would take a fortnight or three weeks to make it fit to receive its shutters: we might use it in the latter part of the year, if the channels were sufficiently advanced. This work might be proceeded with during the monsoon, excepting in the high freshes. The masonry dam at the third channel (Muddoor) is well advanced: it will, I hope, be completed in respect of its length, excepting the upper part of the wing-walls, in a fortnight; but the masonry is yet only one and-a-half feet thick, and we may not have time to complete two and-a-half feet before the freshes, though we may be able to increase it to two feet.

"In the Vijaiswaram branch, the wing-walls will be of such a height as to allow of our continuing to work at them after the river rises in about ten days. The under sluices and head sluices are well advanced, and I hope will be sufficiently prepared for the freshes in a fortnight: the lock also is in the same state; but we shall probably not attempt to put the gates on this season, but shut it off by an embankment.

"I thus expect that all the main masonry work, so far as will be required, will be finished within a fortnight; after which the further raising of the wing-walls, &c., may be proceeded with more leisurely, as the quantity of work will be comparatively small, and it is yet two months to the first high fresh and three and-a-half to the main fresh.

"The rough-stone apron in the Dowlaisweram channel has been begun, and there is a good deal of large stone all along the work ready to be placed against it. I expect a sufficient quantity will be placed along it in a fortnight. With the dam so low as it is at present, the force of the water will be trifling: with about one foot of water going over the annicut, I calculate that the lower water will stand within two feet of the top of it, or there would be four and-a-half feet over

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the rough-stone apron; so that before there is any weight of water going over the annicut, there will be very little velocity at the apron. A great part of the dam is below the level of the sands, where for this year there will be probably no overfall, but the principal part of the rough stone must be thrown where the bed is at present low.

"In the third (Muddoor) channel the rough-stone apron has not yet been begun, but the work is short, and the quantity of stone required small, on this account also, as well as on that mentioned above.

"With respect to the rough-stone dams, I have been greatly disappointed: we have been continually baffled in every attempt to push them out, and they are now in so backward a state that I begin to be greatly afraid that we shall not have them completed even to a moderate height before we are stopped by the freshes. The primary cause of all the delay in this was the failure of our wagon wheels combined with the desertion of this bank by the stream of the river.".

It is in this same report that we find the first anticipation of the inadequacy of the sum sanctioned, and a supplemental estimate for Rs. 1,39,100 accompanied it. The following are extracts from the same report bearing on the question of excess cost:—

"With respect to the progress of the estimate, I regret to state that since my last report the expenditure has been greatly out of proportion to our progress in the work. This has been mainly owing to the circumstances mentioned in my remarks upon the rough-stone dams. In consequence of the failure of every effort to get them established, so as to give us the free use of the water and of the short line of rail-road, we have been limited in every direction, and have been obliged to resort to any means to obtain stone and carry on the works: thus carriage by coolies and by common bandies has been frequently resorted to, working the rail-roads by night: we have also been obliged to build the Vijaiswaram works of brick which is much more expensive, from the impossibility of supplying stone for it. But not only has the expense been increased directly on this account, but indirectly in every way; for, circumstanced as we were, it was impossible to carry on the work more slowly: it was absolutely necessary to put it in a safe state if possible before the freshes. The expenditure has been thus very great during the last three months, and continues so. I had hoped to have terminated our main operations this month, and have put our whole establishment on its monsoon footing, going on with the rough-stone work only; but we shall have ten days more work in June, at least in the masonry work, if the monsoon allows of it.

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"There is another mode of conducting the work which would have certainly entirely prevented all the main difficulties we have met with, and have enabled us to carry on the works economically, and that is, by not attempting to do anything in the way of bringing the annicut into a state in which it would have been of use this year: had we thus arranged to do only half the work we have done, we should have had an ample supply of workmen and materials without any trouble. But these works are not like ordinary works of public improvement; the question is not whether they are to yield nothing or 10 per cent. (the latter considered a most abundant return), so that it matters little whether they take a year more or less to complete, only so that they are done economically, upon which depends whether they cause loss or yield a profit. In every irrigation work of consequence that I am acquainted with, the returns to Government (besides the benefit to the people) have been so great that, even in respect of this only, the question was not how cheaply, but how quickly the work would be executed. In this district this has been the case, still more than in Tanjore. The Woondy talook, upon the irrigation of which Captain DeButts spent a few thousand rupees seven years ago, has actually steadily increased from that time, from a previous average of 80,000 rupees revenue to 1,25,000; and the estimate for next year is 1,30,000; and with this, the improved circumstances of the ryots are notorious. The increase under the new Samalcottah channel the first year has been 10,000 rupees compared with adjoining villages; and there is no doubt it will soon be 20,000, which I believe is about what it has cost. But this even is a small matter compared with the guarding against a famine. The year the Colleroon annicuts were built, there was a scarcity approaching to the very verge of famine, throughout the Indian districts: there is not the least doubt that, had the annicuts been built in two seasons instead of one, the main crop of Tanjore would have been lost to a great extent that year, and that famine instead of scarcity would have extended over five or six districts.

"These are the reasons that made me endeavour to carry the work to such a point in one season as that it would begin to affect the district. A very considerable effect will, I feel confident, be produced this year, in improving the supply of water, so that I have no doubt the revenue will be very materially affected by it; and a very moderate improvement in the supply of water to a great part of the delta will make a material difference in the revenue, where we see an increase of 10,000 rupees in about a dozen villages produced by improved irrigation.

"It has been some additional hinderance to the progress of the works, that for the last six weeks in the very height of the working season, I have been so completely broken in health as to be wholly unable to attend to the works personally, and to be only occasionally even able to attend to business within doors; and this must needs be the case in a measure, notwithstanding that the other officers are so remarkably effective. The loss of even an inexperienced officer would have been seriously felt."

Scarcely had this been sent off when a small flood came down the river and did considerable damage, described in the following letter, dated 15th June, from Major Cotton, to the Board of Revenue:—

"*First.*—I have the honour to report that yesterday the river rose suddenly several feet, and reached the level of the crown of the annicut about sunset. The masonry dam across the third (Muddoor) channel, having been finished in one part only a few days, there were no hopes of saving it if the water passed over it at present. An earthen bank was accordingly carried along the top of it to such a height as the time allowed of, but it was over-topped in the course of the night, and in a short time the water cut through the masonry, which was quite soft, and breached the work. Had we been able to prevent the water from passing over it at this time, according to the ordinary state of the river, it would have had a month more to dry, and would probably have then stood. The quantity of masonry destroyed is not great, and probably the total loss will not eventually exceed 5,000 rupees; but it will be inconvenient, as we shall not be able to get at the work, as we otherwise should, till we have shut off that breach by an embankment.

"*Second.*—This partial fresh is earlier than the earliest of the six years we have recorded. It found us also not fully prepared in the Dowlaisweram branch, as we required still a few days to complete the rough-stone apron, and the rail-road in the bed of the river was still working. Some stone had been placed all along the work, but only a very small quantity in some places. What was of still more consequence, the apron of the under sluices was not completed; abundance of stone was collected close to the spot, and the workmen were placing it against the apron, and another day would have about rendered it secure. In the evening the embankment in front of the sluices was breached, and the water soon breached also the railway embankment below them, and flowed freely through them. Where the loose stone apron was nearly completed, everything appeared very satisfactory, but where there was less stone, there was of course danger of its undermining the lower retaining wall. No mischief however has yet occurred,

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and I hope to get some additional stone thrown in. The water began to pass over the annicut adjoining about sunset, and rose in the night to nine inches above the crown, from which time it remained nearly stationary. The surface of this dam being pretty well set, there was little danger of any injury, especially as the water did not rise high enough to pass over that part of the dam last built, and which is below the level of the sand. The effect of the form of the section appeared most satisfactory. With only nine inches of water passing over the top, for about two-thirds of the length of the annicut, the water below stood within four feet eight inches of the crown; so that the current met the lower water at about 10 feet measured horizontally from the edge of the slope, and 20 feet from the lower masonry. The velocity of the water was thus almost destroyed before it reached the edge of the masonry, and commencement of the rough-stone apron, over which the water passed with little more than the ordinary current of the river. From the appearance of things so far, there seems not the least probability of injury to the annicut, if only the chunam has set sufficiently; but if the water should get through the surface into the soft masonry below, a breach must take place. There is no current along the face of the work to the under sluices, till within 20 or 30 yards of them, and there so trifling that it is only about three miles an hour round the end of the cross wall that separates them from the annicut. The part of the railway that remained in the bed of the river has been mostly washed away, and a good deal of the iron will probably be lost. No other mischief has been done of any consequence, but of course all further work in the bed of the river is stopped. All the wing-walls have been carried above the level of the water, and I hope we shall be able to complete them. As this rise is very untimely, most probably the river will fall again and continue lower than it is now, till the first great fresh, which occurs about the end of July, approaches.

"*Third.*—If it falls a very little, we shall be able to complete the rough-stone apron of the Dowlaisweram branch. The days on which the river reached the height it was last night, for the last six years, were 10th July 13th July, 1st July, 27th June, 27th June, and 27th June. Thus, as we had the freshes far later last year than any recorded of the preceding six years, so we have had them earlier this year than any one of the previous six, giving us a working season of about two months less than the average."

Major Cotton, exhausted by unremitting work and anxiety, had now to go on leave, handing over the work to the charge of Captain (afterwards General), C. A. Orr, R.E., who had from the first been his most able lieutenant and to whom much of the credit of the successful construction of the works is due. On 15th August Captain Orr reported as follows :—

"2. On this (Dowlaisweram) branch, the masonry, so far as it is intended to be built this season, is completed, all but the coping of the lock walls. The earthwork is finished as far I think as safety demands, though a little remains to be performed at a more favourable time, when earth or sand may be obtained from the bed of the river or channel. Nearly three feet of water is still going over the crown of the annicut, the masonry of which has not been visible since the 16th of July.

"3. On the Rallee branch, the wing-walls on this side will be finished, as far as intended to be done this year, by the end of the present week, leaving about 100 cubic yards to be executed hereafter. The under sluices, &c., on the Rallee side of this branch remain as at the date of my former report. The river having fallen so as to enable me to examine, by means of sounding, the condition of the rough-stone dam, I am glad to report that it seems in a sound state; and I am able also to correct the opinion I expressed in my former report, that the sands on either hand, between the dam and the wing-walls, had been cut away. It seems that the level of these sands has been little lowered, and certainly nothing like a

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deep cutting appears at either end, the general level being still some feet above the deep bed of the river. Our exertions have been principally directed, during the last fortnight, to the throwing in of stone on the line of this dam, and more particularly to the prolonging it, on either side, up to the wing-walls.

"4. On the third branch, the wing-walls on the Muddoor side have alone been proceeded with, and they will be finished by the end of this week. The breach remains unaltered."

And on 2nd October he further reports:

"3. The river having fallen below the level of the annicut, I have been able carefully to examine the masonry, and am happy to say that it has, with a few slight exceptions, stood the severe test to which it has been exposed ever since the middle of July remarkably well. The few trifling damages that have been sustained amount only to the loosening, and in a few instances the displacing, of some stones of the upper course of masonry, and have occurred only to those portions of the work which were built with chunam that had been burned for some time, or with a concrete formed of round gravel from the river and of the same partially recarbonised chunam. During the first fresh, some of those portions of the annicut which were built on sand filled in to the height of six and-a-half feet, sunk considerably, but there is now no appearance of the amount of subsidence having increased since the first settlement of the masonry; and it has only taken place, to an extent worth mentioning, where, early in the season before the people were accustomed to the work, sand was hastily thrown in without being sufficiently wetted and trodden down; as was invariably done at a later period. In fact, I consider that the small injuries which have been sustained are all attributable to the use of chunam deteriorated by keeping, to a hasty and careless filling in of the sand, and to the indifferent qualifications of many of the workmen whom we were obliged to employ.

"4. These defects are such as may easily be avoided in the future prosecution of the work, and are quite unconnected with the nature of the section given to the annicut, which seems in every respect to suit the circumstances of the river."

In the meantime, on 16th September, Captain Orr had found it necessary to send in another supplemental estimate for "completing the Gódávari Anicut" amounting to Rs. 3,56,376-8-0, with a letter from which the following are extracts:—

"I have adhered, in three of the branches, to the section hitherto constructed, as the experience of this season seems, as far as we can yet judge, to warrant the belief that, with the advantage of requiring comparatively a small quantity of materials, it is well adapted to the circumstances of this river, where the current even at the top of the freshes is so moderate. Not having had an opportunity of seeing the masonry since the 17th of July, during much of which time the river has, in a very unusual manner, remained at the precise height calculated to do most injury to the work, I am unable to make a decided report regarding the condition in which the freshes have left the masonry, but from the rapid manner the river is falling, I shall probably be able to examine and report on the state of the work by the end of this month. Anticipating no injury, however, I will not detain this estimate.

"It being indispensable, for the sake of obtaining a command of water-carriage, to throw in a large quantity of stone to form a dam across the second or Rallee branch, and it being necessary to have some means, while the work is proceeding, of regulating the height of water, I propose, as Major Cotton intended, to construct the annicut across this branch entirely of rough-stone in the first instance, that it may without difficulty, danger, or expense, be partially lowered or raised at pleasure, and afterwards, if necessary, to finish it off with a similar section to the rest of the annicut, by building retaining walls of masonry, and giving a covering of masonry and cut-stone.

"I have allowed for an entire covering to the annicut of cut-stone, which though forming the largest item of my estimate, I consider indispensable to insure the permanent security of the work; and though costing a large sum at first, it is an outlay that will be repaid in the course of a few years, by the saving of repairs that would otherwise probably be extensively required each year. The stone need not, however, be of any great thickness, except for the coping of the upper retaining wall; for with the current of this river and from the nature of the overfall of the section, the force of the water is nothing so long as the joints of the masonry, by being well fitted, offer no hold nor obstruction. I consider therefore that stones of one foot in thickness, which are readily cut, and easily transported and laid, quite sufficient for the covering of the annicut. For the coping of the upper retaining wall, to resist the battering of the waves, which, from the great expanse of water above the annicut when the river is even 12 or 14 feet high, during high winds and squalls, often beat with great violence on the work, and to withstand the shock of large timber coming down during the early part of the freshes, the heaviest stones we can procure, of one and-a-half or two feet in thickness, should be used.

* * * *

"The Board will observe that I have allowed for superintendence for 16 working and eight inactive months, or a total period of two years; and I shall now explain the mode of proceeding I should propose to adopt for a vigorous prosecution of the works. That my meaning may be readily understood, I annex a sketch of a portion of the river bed, showing the lunkas and sand banks as they appeared last season, and the position of the annicut, temporary dams, and other works. I have reason to think these sand banks are not extensively altered, and that the general outline of the course of the summer water will be much the same this year.

"The first and most essential point being to obtain a command of water-carriage, I would direct all our efforts, in the first instance, to the making up of the Rallee rough-stone dam; after doing which, by lowering a portion of it, or perhaps simultaneously by keeping a part low, I think we should have not much difficulty in forming a temporary dam across the Muddoor branch, a short way above the site of the annicut, to allow us to get at the breach, to fill up and repair it, and to proceed with the construction of the annicut across that branch. Previous to making this temporary dam, however, a canal should be excavated in the sand round the head of Muddoor Lunka, that the water as it was headed back might fill it, and thus give a direct water communication to the Vijaiswaram side. While these operations were being carried on, or as soon as the diminished body of water coming down the river shall allow, it will be necessary to make a temporary dam at the head of Wadava Lunka, to direct the whole stream into the three branches on this side, to give sufficient water for carriage in the first place, and to allow of our proceeding with the construction of the annicut across the Vijaiswaram branch; a part of the work on which I would commence the first moment it should be practicable to do so.

"Thus, or as circumstances, from time to time, should suggest, during the first year, I would endeavour to build the annicut across the Vijaiswaram branch to the height of 11 feet, leaving one foot for the cut-stone; to repair the breach, and complete the annicut across the Muddoor branch, to the same height of 11 feet, to make up the Rallee dam to about nine feet in height, to complete all the wing-walls, and to do as much as necessary and possible to the locks and sluices, leaving the annicut across this the Dowlaisweram branch as it is at present.

"The second year, we should be able to complete all the locks and sluices to build up the rubble masonry of this branch, and that of Rallee to the height of 11 feet, and probably to cover the whole or the greater portion of the annicut with cut-stone.

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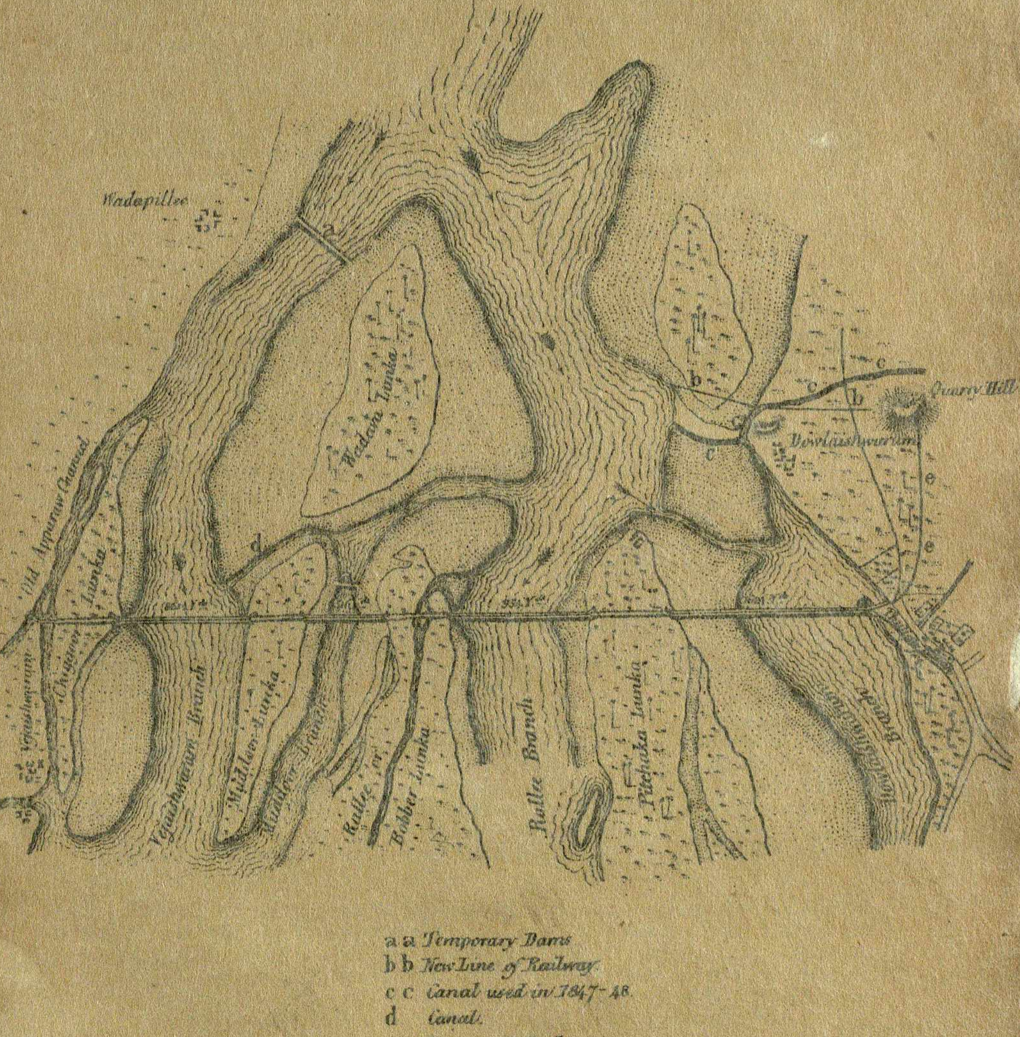
Sketch of the Head of the Godavery Delta showing the arrangement of Railways and Canals for carrying on the works in 1848-49.



a a Temporary Dams
b b New Line of Railway
c c Canal used in 1847-48.
d Canal.
e e Permanent Railway.

Facsimile of drawing facing page 102 of Vol. III of Professional papers of the Madras Engineers.

Furlongs 8 7 6 5 4 3 2 1 0 1 Miles

Fort St George 1859.

REG. No. 1868 — COPIES 320

PHOTO-ZINCO., SURVEY OFFICE, M.

1895

"In this manner two years would be fully employed, and I have thus entered into detail, that the insuperable obstacles which must oppose any attempt at a too speedy progress may be readily understood. These obstacles consist, principally, of the great difficulty, till the working season is far advanced, of disposing of the large body of water coming down the river, and of so managing it that there shall always be enough for the purpose of navigation, while at the same time the stream must be diverted from the neighbourhood of the building operations, and the water drained from the foundations. From the nature of the river, and the great extent of the annicut, the only means of overcoming these obstacles, and attaining the desired objects, are by the formation, at much expense and loss of time, of large temporary dams above, and by the excavation of drainage canals below the site of the work; which operations are so dependent upon the state of the river that no amount of expenditure alone will hasten them many days. There is also, if too much be undertaken, the uncertainty of being able to transport daily a sufficient quantity of stone to complete the work in due time. Although this year we shall have greatly augmented means of transport by boats, and have more use of steam power.

"An objection may be made to leaving, at the end of the season, some parts of the annicut higher than others, as likely to throw a dangerous body of water over the lower portions; but from the experience gained this year, I do not look upon that circumstance as being of much importance. Across the two divisions of the western branch, the annicut will be of the same height of 11 feet, and across the two divisions of the eastern branch, it may also be left with safety, I think, of an equal level of nine feet, though probably it will be advisable at the close of the season to lower the Rallee rough-stone dam one foot or so, to relieve the fall over the masonry at the Dowlaisweram side.

"By carrying on the works as I have proposed, full use of the annicut will be obtained next year during the monsoon months; which is the only season, I imagine, when any cultivation will be carried on for some time, till the people become accustomed to having a regular supply of summer water.

"Three locks only, to provide for the navigation of the three main channels, as Major Cotton laid down the works, are allowed for in my estimate; but eventually, it will be necessary, I think, to avoid interrupting the navigation of the river, to construct two more locks, one on the Dowlaisweram branch and the other near Vijaiswaram.

"Having endeavoured to explain the nature and difficulties of the undertaking, I may be permitted to add that there can be no doubt as to the practicability of constructing the annicut, and that time and money are alone required to complete this great work, which, when finished, will confer such inestimable benefits upon these districts, by securing them from the vicissitudes of the seasons, and while giving wealth and comfort to the people, insuring to the state a certain and great increase of revenue, most favourably disproportioned to the amount required to be expended.

"I have only to add, that the accompanying estimate provides for carrying on the works from this time to completion, and is quite independent of any sums hitherto expended here, or in the purchase abroad of machinery, apparatus or materials. Of these, at least the value of a lac of rupees is now in use or in store, and on the completion of the annicut, they will be available for other works, or may be sold for their then value; probably a considerable sum."

Almost at the very time that this *second* supplemental estimate was being sent on, the Court of Directors was penning the following lugubrious despatch, dated 20th September 1848, about the *first* supplemental estimate of Rs. 1,39,100, which the Madras Government had sent on in July :—

No. 15 of 1848.

OUR GOVERNOR IN COUNCIL AT FORT ST. GEORGE.

* * * *

2. We have perused, with equal surprise and disappointment, your letter of the 8th July last (No. 47), in which you inform us that the whole of the amount sanctioned (Rs. 4,75,752) has been already expended, and that a supplementary estimate of Rs. 1,39,100 has been sent in by Major Cotton; that the works appear to be less than half finished and not even placed in a condition of security against the effects of the heavy freshes of the season; and that you are inclined to believe that a larger sum than that now estimated will be required to bring them to completion.

3. Under these circumstances, and considering that the full operations of the work cannot be resumed until the end of November, you have resolved to await our instructions, having in the meantime sanctioned an expenditure of Rs. 20,000, which is stated to be indispensable not only for the preservation of the works, but for carrying on such as are absolutely required.

4. We fully agree in the opinion expressed by you that the explanation given of the causes of the expenditure so greatly exceeding the estimate is far from satisfactory. We cannot but think that the over-anxiety of Major Cotton to complete the work in the shortest possible time has led him to disregard considerations of economy and even of security to the work itself, and we concur in the remark of the Board of Revenue that "regular and safe measures are greatly to "be preferred to much haste in the construction of public works whatever may "be the contingent advantages of the latter; even in the case of the Godavery "Anicut, in which those advantages were so highly estimated, they were nothing "in the judgment of the Board to that of substituting comparative certainty in "the execution of the works to considerable risk."

5. In the present state of the works, it is obvious that the large expenditure already incurred will be altogether lost, unless the further amount required to complete them is authorized. We have, therefore, no alternative but to give our sanction to their being proceeded with in full reliance on the pledge given in your letter that you will not "give effect to the sanction until you are fully "satisfied that your doing so will secure the desired end beyond the chance of "failure, of which the condition of the anicut after the rains will afford you "ample opportunity to judge."

6. We think it very desirable that, in addition to the scrutiny to which the Board of Revenue have been directed to subject the estimates when sent in by Major Cotton, the work itself should be inspected by one or more experienced Engineer officers, who might report to you on its actual condition and on the plans proposed by Major Cotton to be pursued for completing it, before authorizing any further large disbursement on account of it.

We are,
your loving friends,
(Here follow signatures of 12 Directors.)

LONDON,
20th September 1848.

What, one wonders, would have been the feelings of the Directors could they but then have known that the works for which, with great perturbation, they were sanctioning Rs. 6,14,672 would really cost more than 9 lakhs, and would be followed by others in the same district which would bring the total up to more than 109 lakhs, taking into account the 'Direct charge' only, or to more than 128[*] lakhs including the 'Indirect charges.'

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[*] See Appendix No. 1 'Statement of Expenditure.'

In obedience to the orders of the Court of Directors in the despatch above printed, a committee was appointed to report on the Gódávari works. It submitted its report on 13th January 1849, the main gist of which was that the works had been well designed and carried out, but that the original estimate for them was quite inadequate, and that they would cost Rs. 9,11,209. The committee remarked:

"70. It is scarcely necessary to add that time itself in the construction of the annicut is money. If the work is to increase the revenue, the sooner the increase begins the better: if the increase has been in any measure rightly estimated, it will speedily pay a much larger interest upon the extra expenditure than the rate at which the company borrow money; and a single year of drought, which may happen at any time, would compel all to acknowledge the annicut to be of incalculable value."

The report ends thus:

"73. The committee, reviewing their inspections and investigations, are constrained to record their very high opinion of the science, practical ability, and indefatigable labours of Major Cotton, displayed in the great work under report. It is scarcely possible to place that officer's qualifications as an Engineer of hydraulic works higher than they stood before; but the Godavery Annicut is a new and splendid illustration of the powers of mind and self-devotion, from the exercise of which the country has already so largely benefited.

"74. The committee, in submitting their report, beg leave to add their recommendation that the works may be prosecuted with all possible diligence, and that the opening of the Rallee and other irrigating channels, required to extend to all parts of the district the benefit of the annicut, may also receive early sanction."

The Court of Directors dealt with this report in despatch No. 6, dated 18th July 1849, from which the following are extracts:—

"8. The total amount expended on the anicut up to the end of November 1848 was Rs. 5,03,703, and, according to the committee's estimate, a further sum of Rs. 4,07,506 will be required to complete the work, making an aggregate expenditure of Rs. 9,11,209, or Rs. 4,35,639 in excess of the sum originally sanctioned for that purpose.

"9. Under these circumstances and in pursuance of the instructions contained in the fifth paragraph of our despatch of the 20th September 1848, No. 15, you have resolved to authorize the work being proceeded with, you state that you are still sanguine that the advantages to be gained by the Godavery anicut have not been overrated, and you refer to the opinion expressed by the committee already quoted that, even at its greatly-augmented cost, the anicut will still be a cheaply-constructed work.

"10. However much we regret the imperfect nature of the information which was submitted to us when our sanction to the undertaking was originally solicited, it is obvious that the whole of the large expenditure already incurred must be entirely lost unless the works are carried to completion, and the sooner the country begins to derive the expected benefit from the work, the earlier will you receive some compensation for the outlay in the shape of an increased revenue. We observe that the committee state "that the anicut will, it is expected, be "effective for a large supply of water this season and will, next year, be in all "probability at its full height."

11. We accordingly approve and sanction the course of proceeding which you have adopted."

It will have been seen that, in anticipation of sanction of the Court of Directors to the largely increased estimate, the Government of Madras had already authorized the work being proceeded with, and by 15th May (1849) Captain Orr was able to report good progress thus:

"Para. 1. I have the honour to state that the construction of the Godavery Annicut has, throughout the last month, proceeded satisfactorily; although three days' heavy rain somewhat interrupted progress, and a subsequent threatening rise of the river caused a little delay in commencing the masonry of the Rallee branch.

"2. At the Dowlaisweram side, the lock is ready to receive its gates, the wood work of which is ready, and the iron work in preparation. The head and under sluices are well advanced; the large arches of the former being all turned and the centrings removed. The superstructures of roadway and parapet walls alone remain to be built. The under sluice and wing-wall connecting it with the annicut, are also so far advanced as to require little more than the roadway and parapet walls to complete. A considerable addition has been made to the loose stone apron of the annicut, and a part of the slope of the body of the work has been covered with loose rough-stone, as a protection to it during the freshes. I am anxious, if time allow, to cover the whole of the masonry in the same way, and hope to be able to do so.

"3. On the Rallee branch, unfortunately, just as we were about to begin the masonry of the portions I purpose to build this season, the rise of the river, which I have mentioned, occurred, and caused a loss of some days of invaluable time. A commencement has, however, been made, and I trust to have no difficulty in completing as much as I proposed to undertake this year. The under sluice is much advanced, only two of the 15 arches remaining to be turned. After which, the superstructure alone will remain to be built; and for its completion there is ample time before the river rises to such a level as to interfere with the work. The loose-stone apron of this sluice is made up to a width of nearly 40 yards, and the work is otherwise perfectly secured with rough-stone, both in front and rear. The floor of the head sluice is finished, and the piers are in progress.

"4. On the Muddoor branch, considerable progress has been made, and by the end of this week I hope the additional half yard of height will be given, leaving, of masonry, only a portion of one wing-wall, and the opening for drainage, to be built up during the remainder of the month. The loose-stone apron is commenced, and will be rapidly pushed forward, as soon as, the masonry being completed, the boats may be brought alongside the work.

"5. On the Vijaiswaram branch, with the exception of the drainage opening, and portions of the wing-walls, the masonry is completed to a height of nine feet above the deep bed, or to three feet below its ultimate level. The front and rear apron are made up for 700 yards of the 870, of which the length of this branch of the work consists. The large arches of the under sluice are all but keyed, and would certainly have been finished but for the destruction of bricks by the heavy rain. The head sluice and lock are advancing to completion, and will, I hope, be ready in good time.

"6. Altogether, I may report that the works are so far advanced that the time remaining before the freshes seems amply sufficient to enable us to complete those portions we have undertaken, and to make all safe by an abundant use of loose rough-stone."

But less than a week after Captain Orr had thus expressed his belief that he could make "all safe" before the first freshes, he had to write as follows:—

"Para. 1. I have the painful duty to report the occurrence, yesterday afternoon, of very serious damage to that portion of the annicut which I have reported as all but completed across the Vijaiswaram branch of the river.

"2. The front retaining wall was built quite across; only a small opening at one point, one foot square, being left near its base for the purpose of draining off the water, which oozed through the main temporary dam, and through a semicircular embankment thrown round the opening, as an additional protection. The

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latter embankment was made principally of clay, was revetted on both sides with grass rollers, and being so strong, and the same height as the annicut, was considered by me quite sufficient protection, even in the event of the main dam giving way. Things were in this perfectly satisfactory state, and the final closing of the opening was only delayed, that the adjoining masonry, being new, should have a few days to set before being subjected to the action of water. The river some days ago rose, in 48 hours, five inches, in addition to a similar rise which took place about a week before, but since Monday evening it seemed so steady, that I was in hopes that the threatened danger of a fresh had passed. Yesterday afternoon, however, the river rose again suddenly, and at about 4 P.M. a very severe squall of wind broke over the works, blowing right down the river, which piling up the pent-up waters against the dams, caused them to breach. Being prepared for such an occasion, I still expected no injury to follow, but unfortunately, we had not guarded against the unlooked for, and at this season the unprecedented contingency of a fresh accompanied by a gale causing such a rise of the river as 18 inches in an hour, and that too while the river was passing freely over the whole length of the Rallee dam, and flowing two and-a-half feet deep through the Dowlaisweram under sluices. The consequence, I regret to say, was, that the small semi-circular dam being topped by the waves, and soon breaching, brought such a pressure of water against the new and unbacked retaining wall, that it gave way, and before the extension of the damage could be arrested, about 22 yards of the annicut, on each side of the opening, were washed away, and a breach some 44 yards in width, formed in the centre of the work.

"3. On the Muddoor branch, both the dams went in the same manner, but the masonry, being not so new, and being backed by earth, did not so easily give way, and allowed time for measures being taken to save it.

"4. Of four deep boats, unloading-stone for strengthening the Rallee dam, two, partly unloaded only, were carried by the waves right over, or rather through the dam, as they displaced the upper strata of stones; another was partly carried on to the dam, but was got off afterwards, and a fourth was sunk in front of the dam.

"5. Several other boats were also sunk, but the only damage to be particularly deplored is that occasioned to the Vijaiswaram Annicut, as its situation is so inaccessible at all times, and now completely so, since the water has been lowered by escaping through the breach.

"6. I have scarcely had time for considering the best mode of repairing this disaster, but I am now throwing into the breach rough-stone from that deposited for the apron; and if I can close it in front, or make up a dam at the head of Wadava Lunka, I hope all will still be well, though the time before us is short, and the appearance of the weather most threatening, it being more like that of the 20th June, than the 10th of May.

"7. We have been particularly unfortunate this season in having an unusual body of water in the river. There have been three distinct summer freshes, such as we have no previous record of. One at the end of January, one in the middle of April, and this in May. Last year, Major Cotton was obstructed and thwarted in all his efforts by want of water, while this year the works have been delayed, and finally injured, by these repeated unseasonable freshes.

"8. I shall take an early opportunity to report the measures I adopt to retrieve this disaster; and in the meantime I beg to assure the Board, that no effort will be spared by myself and the officers employed, to recover from the effect of this severe check to our progress."

This untimely fresh however soon subsided, and before the regular season for floods the damage done was repaired; on the 1st June Captain Orr was able to report as follows :—

CSL

"2. On the Dowlaisweram side, the masonry of the lock and sluices is so well advanced, that its final completion has been deferred on account of more pressing labours, but these works will be finished this season. The loose-stone apron of the annicut is being added to, and other defences made up, with rough-stone.

"3. Being encouraged by the favourable change in the weather, I renewed the building of masonry on the Rallee branch, and have completed to nine feet the section on the eastern side for about 120 yards, from the wing-wall to the rough-stone dam. On the western side, we shall in all likelihood complete an equal distance, leaving to be built hereafter, about 700 yards, which are at present closed by a rough-stone dam six feet high above the deep bed. The under sluice is so well advanced that it will certainly be finished in good time.

"4. On the Muddoor branch the body of the annicut is completed to a height of 10½ feet, and the rough-stone apron is made up to an average of 15 yards in width. The wing-wall on the eastern side is not ready, but will be completed in good time. This portion of the annicut, being half a yard higher than the others, we shall probably be able to cover the slope of the apron with rough-stone, after our operations on the other branches are stopped by the rising of the river.

"5. On the Vijaiswaram side, the western wing-wall is built, and the body of the work completed right across to a height of nine feet. The rough-stone aprons, both in front and rear, are made up to an average width in rear, of 15 yards, and the greater part of the slope of the masonry apron is covered and protected with loose-stone laid on it. The eastern wing-wall will be ready in a few days. The lock and sluices at Vijaiswaram are not so well advanced as I expected them to be, owing, chiefly, to the difficulty of making sufficiently good arch bricks from the indifferent clay found in the neighbourhood. These works, however, being raised beyond the reach of an early fresh, will, I have no doubt, be finished this year."

And on 16th of the same month:

"*Second.*—On the Dowlaisweram branch, the rough-stone apron, being considerably strengthened, and the western wing-wall well protected with rough-stone, the security of the work, during the approaching freshes, appears to be insured. We are still adding to the rough-stone defences, and shall be so employed till the last moment.

"*Third.*—On the Rallee branch, the building of the body of the work was some days ago discontinued, after the completion of about 126 yards of the section to nine feet on each side, connecting the rough-stone dam with the wing-wall and the under sluice. The masonry of the under sluice is being proceeded with, and will be finished shortly.

"*Fourth.*—On the Muddoor branch, the eastern wing-wall, which was not finished last month, is approaching completion. The apron being made up, and the greater part of the slope protected by loose-stone, this portion of the work is fully prepared for the rising of the river.

"*Fifth.*—On the Vijaiswaram branch, the masonry being completed early in this month, the work now being carried on consists of embanking, between the wing-wall and the sluices, and the building of the masonry of these, and the lock; which are well advanced."

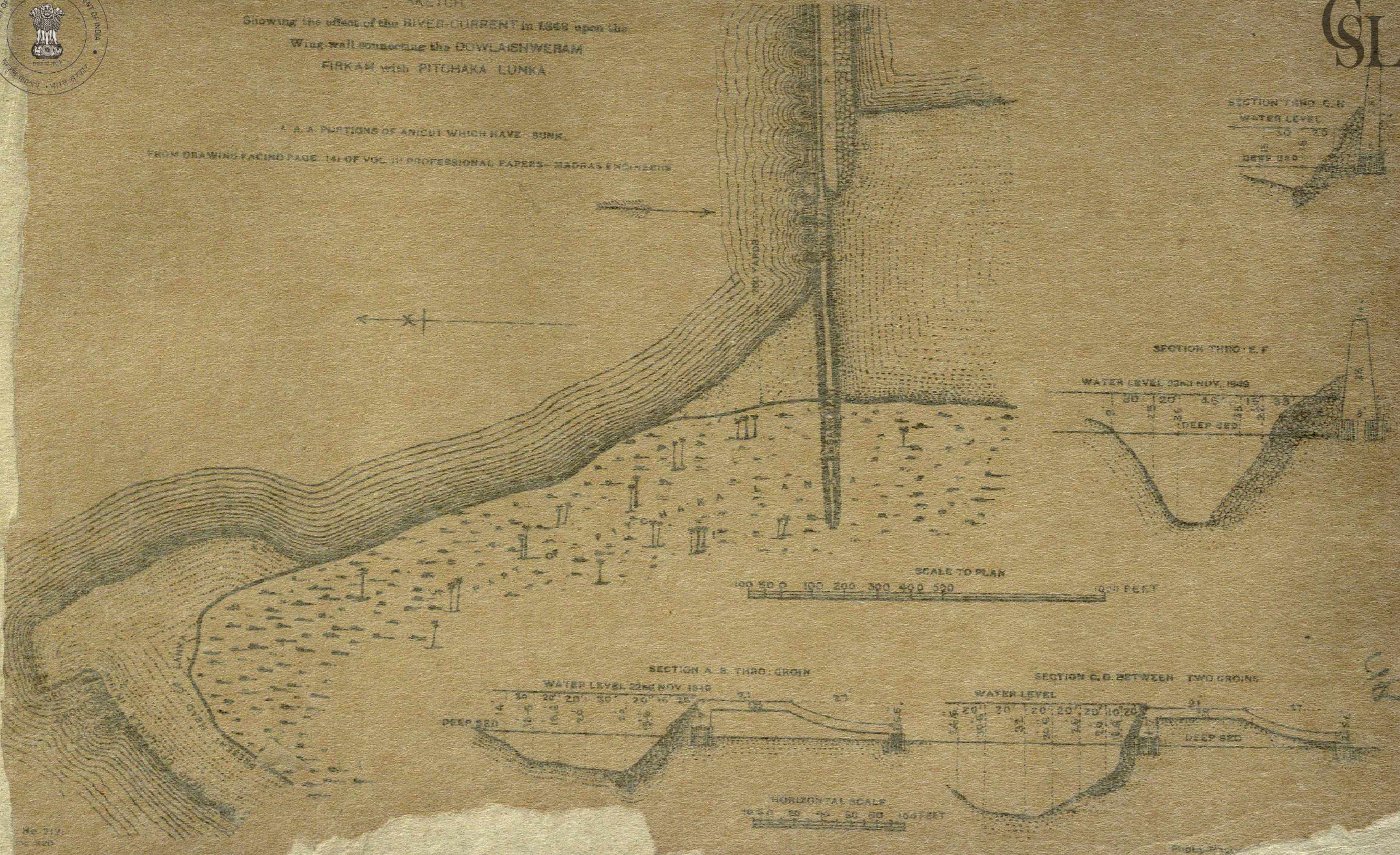
The works were severely tried by high floods on 6th and 16th September, the latter being accompanied by a tremendous storm which did considerable damage to the floating plant used for carriage of materials across the river to various portions of the work. It did not appear at the time as if these floods had in any way injured the works themselves, but later on in the season, some 300 feet in length of the anicut at the extreme right end of the Dowlaishweram branch settled and cracked. The primary cause of this was undoubtedly the projection into the stream-way of the wing-wall, which resulted in a lateral scour along its face and that of the adjacent part of the

SKETCH

Showing the effect of the RIVER-CURRENT in 1849 upon the Wing-wall connecting the DOWLAISHWERAM FIRKAH with PITCHAKA LUNKA

A. A. A. PORTIONS OF ANICUT WHICH HAVE SUNK.

FROM DRAWING FACING PAGE 141 OF VOL. II PROFESSIONAL PAPERS— MADRAS ENGINEERS.



No. 213

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CSL

anicut; but eddies set up by the stone groynes, which had been deposited in front of the work in order to stop this scour, probably expedited the damage they were intended to avert. The following letter of Captain Orr, dated 27th November, and the sketch facing this page, which accompanied that letter, clearly explain what had occurred:—

"As directed in your letter No. 878 of the 15th instant, I have the honour herewith to submit a sketch of the position, relatively to the lunka, of the wing-walls near which the damage to the annicut has occurred, showing the defences erected during the last two years, and, by the sections, the effect of the lateral current caused by the projection of those walls from the natural bank of the lunka.

"2. In 1848, a considerable quantity of stone was thrown in front of the wing-walls, but little in front of the annicut, owing to the early and sudden arrival of the first fresh. Fortunately, no greater rise of the river than 20 feet on our standard having that year occurred, no injury was caused by the set from off the wing-walls, although the effect of that set was so marked as to induce the committee subsequently to make an allowance in the revised supplemental estimate of 2,400 cubic yards of stone, which being thrown in front of the wing-walls, and annicut would, it was considered, render them secure. Last year, accordingly, a large quantity of stone was deposited, before the freshes came down, in front of the annicut, for a distance of nearly 200 yards from the wing-walls, forming groins of considerable size, and a front rough-stone apron several yards in width. The deposition of stone was only stopped by the coming down of the river, but I imagined that enough had been then placed to protect the work for a season; as it probably would have done in an ordinary year. After the rising of the river, upwards of 100 boatloads, or more than 2,000 tons of stone, were thrown in front of the wing-walls, and their foundations have consequently been perfectly protected; although as the sections will show, the sand only a little way in front has been removed to a depth of 26 feet below them. The accompanying sketch and sections will also show that, where the groins in front of the annicut are, the foundations have not been laid bare, but that they are only exposed, and the annicut consequently injured in the spaces between the groins, where the stone, being inadequate in quantity, has sunk into the hollow excavated by the set in front. Had a mass of stone equal in section to any one of the larger groins been thrown in front of the work for 200 or 300 yards from the wing-walls, it seems evident that no damage would even this year have resulted. The necessity for such a mass of stone was not contemplated; nor, if it had been, could more stone have been deposited last year. This season, I hope to have ample command of stone; and either a large quantity may be thrown in as a defence to the foundation, or the wing-walls and embankment may be removed, and the annicut extended to the natural bank of the lunka. The former will be more economical, but as long as the wing-walls project into the bed of the river, so long will there exist a constant source of danger to the work; for as the action of the lateral set is carried on while the river is in flood, it is impossible then to know the effect being produced, or to do anything to arrest in time its evil consequences. The extent and power of this lateral current may be inferred from the fact that, during the height of the freshes, the water at the end of the wing-walls next the lunka stood 18 inches higher than at the point abutting on the annicut, and that there was a fall of at least 15 inches more, making together a fall of two feet nine inches in a distance of about 300 feet, which would be sufficient to give a velocity of about nine miles an hour in excess of that due to the river passing over the annicut.

"3. Twenty thousand cubic yards of stone costing, say, Rs. 10,000, may probably be sufficient to protect this part of the annicut; but considering that the safety of this great work is in question, I hope that the more expensive, but more effectual, course of extending the annicut to the lunka will be decided upon.

GSL

"4. Nearly 700 yards of the Rallee branch being closed by only a rough-stone dam, six feet in height above the deep bed, or three feet below the level of the crown of the annicut, a strong current in consequence sets from this side towards that branch round the head of Peetcheka Lunka. Three stone groins were made at the head of the lunka to protect it from being acted upon, and they succeeded in preventing any great loss of land during the first two freshes; but during the last and greatest, and longest continued flood, the water having stood high over the bank, a fall seems to have been established over the edge of the lunka on the Rallee side, a little lower down than the groins. This fall cut away the lunka behind the groins, and swept away the large portion of the head of the lunka shown in the sketch as lying between them and the present bank. From the nature of the river bed a certain amount of set must always exist round the head of Peetcheka Lunka; but when the annicut shall be of one uniform height, that set will be reduced, and its effect will be no more than can be easily counteracted by the construction of a few rough-stone groins. I anticipate no danger from this source, although it will no doubt be necessary to incur yearly, for some seasons after the completion of the annicut, a small outlay in raising defences against the encroachments of the river on its banks and on the heads of the lunkas. No conclusive judgment regarding the effect on the currents of the river on the annicut when completed can as yet be formed, as the work is of such unequal elevation across the different branches; but that effect will probably be the equalisation of the level of the river bed above the annicut, and the removal thereby of the tendency of the stream to take particular sets. There are three points which must be guarded before the next great freshes, and every effort should be made to have them well protected by rough-stone groins, during the interval of several weeks which occurs between the stoppage of building operations by the first rise of the river and the arrival of the early great fresh. The points I allude to are, the heads of Peetcheka and Muddoor Lunkas, and the bank of the river above the Vijaiswaram wing-walls.

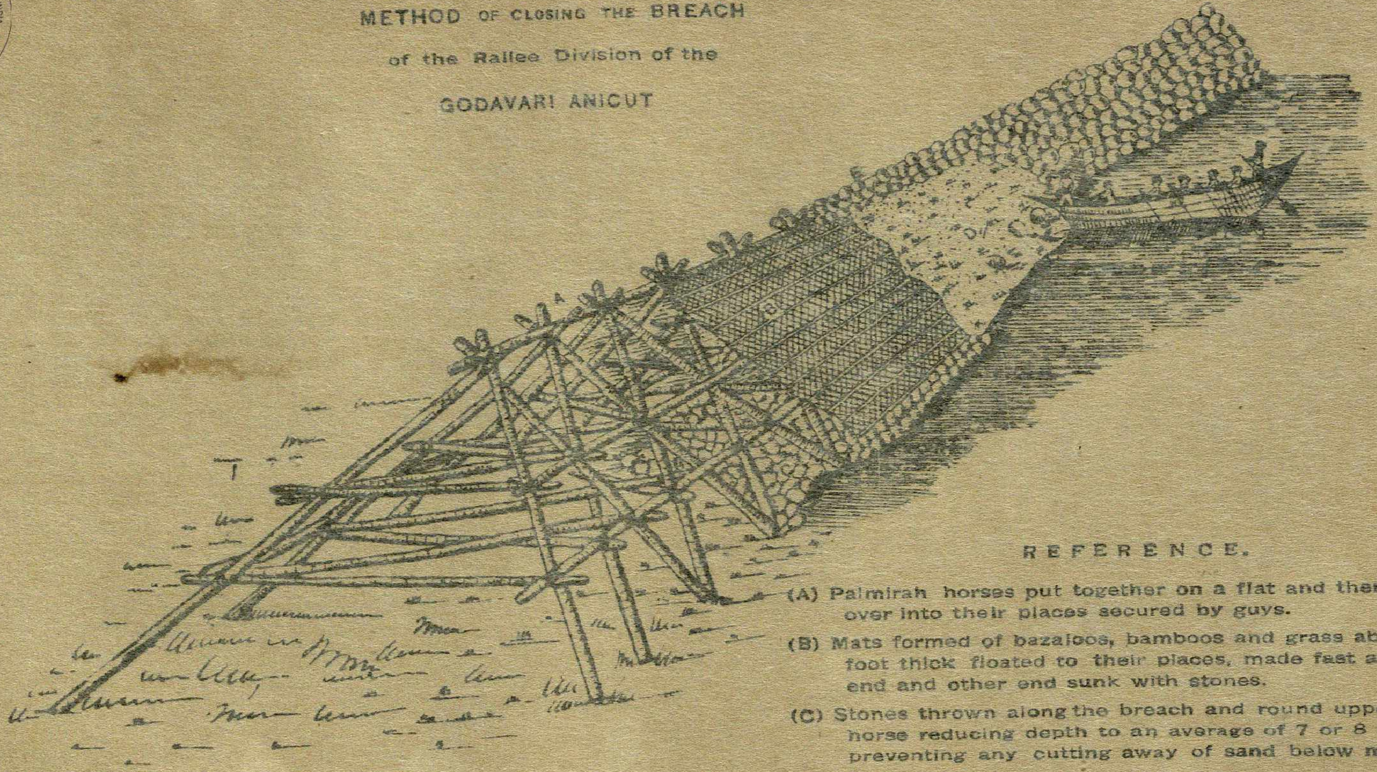
"5. I herewith forward an estimate amounting to Rs. 25,709-8-0 of the probable cost of removing the Peetcheka Lunka wing-walls, and extending the annicut to the natural bank."

This accident is of much interest on account of the warning it furnishes against undue contraction of the waterway when building a dam across a sandy-bedded stream, and also on account of the illustration it affords of the treacherousness of groynes when used in a river of greatly varying discharge, height, and velocity of water, and of unstable banks and bed. It is evident that in this case the groynes just above the anicut formed corners, in which both the onward and the lateral movement of the water being checked, eddies were set up, and eddies are particularly potent in scooping out sand. Projections from the *up-stream* face of a dam should be avoided, unless the bed between them is so hard, or so artificially protected, that there is no possibility of its being disturbed; along the *down-stream* edge of the aprons of a dam, there is not the same objection to 'hanging' groynes, because in that position, though they prevent lateral currents, they do not arrest the onward flow of the water, and eddies are not set up.

The groynes at the head of 'Pitchaka lanka' also, it will be seen, though, at certain stages of the river, they appeared to be effecting the purpose for which they were intended, eventually did far more harm than good; at some stage of the river they doubtless caused heading up of the water and considerable difference of level above and below them, which resulted in violent disturbance destructive to bed and banks. A similar result is by no means an uncommon experience in the Gódávari river, even when the groynes used have not been so directly opposed to the set of the stream as appears to have been the case in the instance under notice.

CSL

METHOD OF CLOSING THE BREACH
of the Rallee Division of the
GODAVARI ANICUT



REFERENCE.

(A) Palmirah horses put together on a flat and then tilted over into their places secured by guys.

(B) Mats formed of bazaloos, bamboos and grass about one foot thick floated to their places, made fast at upper end and other end sunk with stones.

(C) Stones thrown along the breach and round upper leg of horse reducing depth to an average of 7 or 8 feet and preventing any cutting away of sand below mats.

(D) Sand and clay.

(E) Stone thrown in to close after the mats were put down. Depth of water 26 feet.

Copy of drawing facing page 144 of Vol. III professional papers Madras Engineers.

Photo-Zinco., Survey Office, Madras.
1896

Reg: No, 1837
Copies 320

The state of progress at the beginning of the working season of 1850 is summarized in the following extract from a letter* of Mr. H. Forbes, Sub-Collector of the district, who, from the commencement of the work, had rendered invaluable assistance in collecting labour and materials for the work :—

> "8. At the commencement of the present season, therefore, the position of the works was as follows :—An annicut nine feet high was across the Dowlaisweram branch of the river, 1,400 yards in length, with a wing-wall and high embankment 250 yards in length uniting it to Peetcheka Lunka; an annicut of similar height and 900 yards long closed the Vijaiswaram branch; and that at Muddoor was closed also by an annicut, 520 yards long and $10\frac{1}{2}$ feet high. The subordinate works were all completed, excepting the head sluice and lock at Rallee. Thus the only escape for the whole summer stream of the Godavery was down the Rallee branch of the river; and it was in that very branch that an annicut was to be built. A temporary dam formed of loose stone had been made in 1848, and strengthened in 1849, both to keep up the water for purposes of navigation, and to prevent the stream cutting too deep a course in the bed of the river. The water escaping both through and over this rough-stone dam, the objects to be attained were to make it water-tight, and of such a height as would turn the stream down the Dowlaisweram and Vijaiswaram branches, where the water could escape through the head and under sluices. It was unfortunate that there was considerably more water in the river than is at all usual in the summer; heavy rains in the Nagpore and Hyderabad countries having unexpectedly fallen."

The 'temporary dam' to close the Ralli branch and enable that portion of the anicut to be built gave much trouble. Mr. Forbes, in the same letter just quoted from, says: "The river breached the dam for about 50 yards "in February (1850), and no sooner was the damage repaired than a more "extensive breach of about 80 yards was made; this was closed to within "25 or 30 yards, when again the water proved too powerful, and the breach "was a third time widened to 80 yards."

This last breach occurred early in April. Owing to the scour at the breach, the depth of the water at the place was between 20 and 30 feet, and the rush through the gap was great; the closing was therefore no easy matter; the method of carrying it out is shown on the sketch on the opposite page copied from the one sent in by Captain Orr. By the 23rd April the gap was closed and made good with stone, and "the † Gódávari with a million "and-a-half cubic yards of water passing every hour was turned aside." The anicut across the Ralli branch could then be completed, and on 8th June Captain Orr reported thus about it:

> "2. The rubble masonry of the annicut across the Rallee branch having been completed on the 25th ultimo, it has already had a fortnight to set. The body of the annicut is now carried quite across the river, to a height varying from $10\frac{1}{2}$ to 12 feet. The covering, with dressed stone, of the surface of the Dowlaisweram division of the work, will be finished in eight or ten days; that of the surface of the Vijaiswaram division is well advanced, but can scarcely be finished this season, unless the river be late in beginning to fill. The repeated interruptions of water communication, by the giving way of the Rallee dam, caused a loss of nearly two months of the working season at Vijaiswaram, and thereby has prevented such progress there as I expected at the beginning of the year to have made by this time. The slope, and a portion of the surface of that part of the work will however be covered with dressed stone, and the rough apron has been made up to a very secure extent. The rough apron of the Rallee division of the annicut is being rapidly laid, and will be ready in a few days."

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* No. 66, dated 8th June 1850.

† Mr. Forbes' letter, No. 166, dated 8th June 1850

CSL

It now seemed as if all serious difficulties were over. But the river did not submit to the curb without a further struggle, and only a fortnight after the date of the letter just quoted from, Captain Orr had to write thus:

> "The river began to fill on the 9th instant, and has risen steadily till it is now passing 10 inches deep over the highest part of the annicut. While the water was rising to the level of the annicut, the whole river passed through the Dowlaisweram and Rallee under sluices, which discharged it with intense and increasing velocity. On Monday morning, the 17th, it having been observed that the rough-stone apron behind the Rallee under sluices had sunk, the vents were closed, and immediate measures were taken to fill up the whole left behind the rear retaining wall. By 2 P.M., some progress had been made in replacing the stone, and I considered the work safe for the short time required to make up the apron to its full breadth; when suddenly, the pressure was seen to force the sand from beneath the foundation into the hollow behind the rear retaining wall, and instantly a portion of the masonry apron fell in, followed by the subsidence of one of the piers. Pier fell after pier, but the tenacity and massiveness of the masonry was such, that in falling it formed a dam, preventing any great rush of water, and thereby giving time for measures being taken to check the extension of the damage. Up to this time, seven out of the fourteen piers have fallen, leaving the two abutments and seven piers still standing, though two of the latter are much shaken. No change has taken place since last night; and as rough-stone is rapidly being thrown in to protect what remains of the sluice, I trust no more of it will be lost, and that no breach at the spot will be formed. If successful, as I hope, in preventing the latter, the rebuilding of the sluice will be no difficult matter, and will only affect the completion of the work so far as the loss of the use of the sluice will delay the lowering of the level of the river at the end of the freshes.
>
> "3. The cause of this misfortune is clearly the inadequacy of the masonry apron, which instead of being 25 feet, ought to be 20 yards wide at the least, in rear of the vents, and the insufficiency of the rough-stone apron, which, though made far stronger than was originally intended, and appearing substantial enough, as far as my judgment and experience could decide, has proved quite unequal to resist the force of the discharge through the sluice, even when the anniuct is only 10′ 10″ instead of its ultimate height of 14 feet. The rough apron in rear of the Dowlaisweram under sluice, although exposed to a more severe test, has hitherto shown no signs of weakness, which I attribute to its having been severely tried three successive years, and at the end of each greatly strengthened by the addition of more stone, till it has acquired sufficient thickness and stability. The Rallee sluice apron unfortunately had not thus been gradually tested. As a matter of precaution, however, I have partially closed the vents of the Dowlaisweram sluices, and will take the first opportunity to examine and, if necessary, to further strengthen its apron.
>
> "4. The annicuts look well; but owing to the accident to the Rallee under sluices, preventing the discharge through them assisting to fill the lower bed of that branch of the river, the fall of water over that division of the annicut is much greater than I expected, and tries the rough apron severely."

On the 8th July (1850), Captain Orr reported that "two more of the piers "of the Rallee under sluices, Nos. 1 and 2, sank slightly," and on the 18th of the same month, "The Rallee under sluices remain exactly as they were when "last reported on."

Soon after this, Colonel Cotton returned from leave and again assumed charge of the works. On 12th December, he sent in an interesting report, from which the following is an extract:—

> "I have for some time been occupied in preparing a third report upon the Godavery Delta, showing the present state of the project for its irrigation; and I had hoped to have sent it in long ago; but it has involved so many inquiries,

and I had so much to learn, on resuming charge of the division, respecting what had been done, and what had happened in my absence, that it is still incomplete. I am now under the necessity of sending in an estimate for the extension of the Vijaiswaram Branch Annicut, without waiting for the completion of the general report, as the advanced state of the season will not allow of further delay.

"The overfall over this branch of the work has greatly exceeded that of any of the others, and what I had calculated upon. This season, it was six feet when the lower water was level with the crown of the annicut, and the force of the water in that state of the river was very great. The rough-stone apron sunk greatly, and the bed of the river below the work was deepened to a considerable distance. The sinking of the rough aprons, to a certain extent, is indeed to be expected for the first few years, and they will require to be repaired till they have attained to a permanent state; but the amount of sinking in the Vijaiswaram branch has been much greater than in any of the others. This great overfall has been owing to the following causes:—

"*First.*—The deep channel of this branch was originally two feet below that of the Dowlaisweram one; so that the annicut there, being brought to one level with the latter, is in fact two feet higher.

"*Second.*—The fall of the bed of this branch of the river below the annicut is much greater, viz., three feet a mile; so that when the river is not more than half full, the fall of the surface of the water, and consequently the current of the river is greater than in the other branch. When the river is full, the surface of the water has the same fall as in other places, and the current is not then greater. But the time when the water has the greatest power in passing over the annicut is when the river is less than half full.

"*Third.*—There is a broad and high piece of lunka land on the Vijaiswaram side of that branch, up to which the annicut has been carried; and as it is only three or four feet below the flood, I considered that if the annicut extended to it, it must have sufficient length. And now that I see how great a fall the water, has over the work, I am surprised that the lunka land had not been cut away so as to form a wider channel at that point.

"*Fourth.*—The Muddoor branch, which falls into the same main channel of the river below the annicut, had been long so much choked by the large Lunka of Wuddevany just opposite to its head, that it was a good deal filled up; and consequently the quantity of water passing over its annicut is for the length of that dam, much less than it ought to be. The overfall on this was much less than over any of the others. This evil will, however, correct itself, and it is already greatly diminished. An entirely new channel has been formed by the river above the work; the corner of Wuddevany Lunka has been cut away; and the stream now comes direct to the Muddoor Annicut. In the same way, the channel below the annicut will also be gradually cleared out; and as more water is discharged over this dam, the Vijaiswaram one will be proportionally relieved. In the meantime the Vijaiswaram Annicut has been, from these causes combined, exposed to a trial which I certainly did not anticipate.

"It must be observed, that the Muddoor branch has not yet been covered with cut-stone, and it is therefore one and-a-half feet lower than that of Vijaiswaram. I propose to cover only the slope of the former work this season, leaving the top at its present level, in order to hasten the clearing of that channel of the river; and in another year, probably, it will be nearly as clear as the others.

"But though this will reduce the overfall over the Vijaiswaram branch, I am of opinion that that work must be lengthened. The effect of so great an overfall upon the bed of the river for a considerable distance below, where there is nothing but sand to resist it, is very great; and I think, unless the work is lengthened, the bed will continue to wear away to a dangerous degree.

"The work has certainly had a more severe trial this year than it will have in future; as it was in an unfinished state, and the masonry quite soft when the freshes went over it; so that in several places the cut-stone, from having been left incomplete, has been ripped off. The rough-stone apron was made up to a great width, and contained, as I am informed, perhaps double the quantity allowed in the estimate: yet it will require a great additional quantity of stone this season. In fact the quantity swallowed up very far exceeds my expectation. Unless the force of the overfall is reduced, the wearing of the bed below will continue to an extent that I cannot calculate, and a wider waterway seems to me the only remedy.

"The length of the embankment across the Lunka land, from the Annicut wing-wall to the proper bank of the river, where the under sluice and head sluice are situated, is 600 yards. Of this I propose to cut away 400 yards, and to extend the annicut that length. The Lunka land here is so much higher than the crown of the annicut will be, that it will be necessary to cut channels through it, both above and below the work, to hasten the sweeping it away by the current.

"The cost of the extension of the Dowlaisweram branch, 25,000 rupees, having been, according to the Board's letter of 22nd January last, charged to the contingencies of the last estimate, the present work cannot be executed out of the balance now in hand; the estimate of work remaining to be executed requiring all that balance, allowing only for such minor contingencies as may yet occur.

"I have, therefore, the honor to request sanction for the amount of the present estimate, viz., Rs. 65,742-4-0. The work can be executed this year, and it ought to be so.

"In the report that I hope soon to forward, there are many additional proofs of the great value of water here, besides those contained in my former reports. I am happy to say that the annicut is in effective operation, so far as the channels are opened, and that they have now had water in them without intermission for six months, instead of for twenty or thirty days only, as formerly; and I hope the work of this year will not require us to lower the water in the river much; so that the channels will be supplied throughout the dry season for the first time.

"I am in hopes that within two or three weeks the eastern main channel will be opened, and the centre one in the course of two months. There will then be water in five lines of channel during the hot season; and thus each part of the delta will have proof of the effects of the annicut."

It is convenient to here depart somewhat from chronological sequence and state what came of Colonel Cotton's suggestion that the Vizéswaram section of the anicut should be lengthened. He could not get sanction for carrying it out in the working season of 1851, so he prepared for that year's season of floods * "by laying a very strong apron of rough-stone of a much larger size "than that hitherto used, and carefully packing it, so that from what we "have seen already, it seems impossible that it can be at all shaken by the "overfall. A rubble wall two yards thick is also being carried along the "whole length of the work there, resting on the old loose-stone apron, at a "distance of twelve yards from the solid masonry dam: up to this the large "stone is packed; and beyond it, for a breadth of about 10 yards, will be "loose-stone, which, as the stones before placed there have sunk three or four "yards deep, will form an apron that can scarcely be undermined.

"The annicut having stood with the apron in its former state, we have, of "course, every reason to hope that it will stand now that the old apron has "formed for itself such deep foundations, and is covered with heavy stone.

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* Letter, No. 58, dated 24th February 1851.

"The overfall will also be diminished, in consequence of the Muddoor branch "having so much opened since the beginning of last monsoon. There is now "a clear broad channel leading direct to that dam; and the channel leading "from it is also gradually clearing; so that it will in future carry off more "nearly its due proportion of water, and thus relieve the Vijaiswaram branch."

After the floods of 1851, he wrote: *

"The experience of the previous freshes had shown a mistake that had been made by me in the planning of the work; and had I waited in hopes of getting the sanction of the extension in time to execute it this year, and made no other preparation, I should have had no right to hope that the present monsoon would pass over without serious mischief to the work. As it is, the improvement to the apron, planned and executed by Captain Orr, has been so effectual that, notwithstanding the powerful overfall to which that part of the work has been exposed, there has not been the least alarm about it throughout the freshes; and though we have not yet seen the work uncovered, I have every reason to hope that it is now sufficiently secured, and will not require to be lengthened."

And on the same subject in his letter, No. 29, dated 29th January 1852, he wrote thus:

"As it may well be asked, how did this mistake of making the Vijaiswaram dam too short occur? And the answer to it is of great importance, with reference to future works. I answer, first; it was built just the same as the other branches, that is the full width of the channel. If then there was so much greater a force of water over it than over the others, why had not the river cut itself a wider channel at that place? The only way I can account for this is, that the earth on each side of the channel at that place was tougher than in the others. On examining the sides of the river throughout, it will be found that there is every variety of soil, from the most fusible or soluble material to the strongest clay: in one place the earth melts like sugar the moment the water touches it: in another it will be seen standing in the channel of the river with the water falling over it, exactly like a layer of rocks, which anybody would suppose it to be if they had not examined it. The actual breadth of the channel, therefore, is not a sufficient criterion: the current at the spot when the river is nearly full must be observed, and compared with that in other places. In order to determine what the overfall will be, it is not sufficient to take the mean current of the river, and consider it as applicable to each particular spot."

The increased protection carried out proved efficient, and the work was never lengthened.

Completion of Anicut and Head-works.

The working season of 1851 and the early part of the following one were devoted to rebuilding the Ralli (now called the 'Bobber-lanka') Under sluices and finishing off the Anicut and Head works; their virtual completion may be considered to have been achieved by the end of the official year 1851–52 (31st March 1852), for on 14th April 1852, we find the following report sent in by Colonel Cotton:—

"I have the honor to report for the information of the Board the following results of an examination of the annicut, lately made by Captains Orr and Hutchinson and myself.

"2. Commencing from the Dowlaisweram side—

"*1st.*—The lock is in perfect order: no expense has been incurred on this work from the first (five years). I cannot help here mentioning the excellent workmanship of the lock gates; as I think they reflect much credit on Captain

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* Letter, No. 400, dated 14th November 1851.

CSL

Hutchinson. Considering that nobody here had any experience in such work, and that the locks are 15 feet wide, and 22 feet high, it is remarkable that they should have been made and hung so as to act perfectly without the slightest difficulty or alteration from the first.

"*2nd.*—Head sluice, also in good order, and without repairs from the first.

"*3rd.*—Under sluices, the same, with the exception that we have had to throw in a prodigious quantity of rough-stone for the apron. It has repeatedly sunk one or two yards, and must now contain an enormous quantity of stone. It seems, however, now to be nearly settled, as it has sunk very little of late.

"Both these sluices have two defects. One is that, being on the lee side of the river, in the freshes, vast quantities of drift wood accumulate against them, and often prevent their being close shut. No evil has arisen from this as yet; but it seems very desirable to free them from anything which might tend to endanger them. Various plans have been thought of, but none that seemed to me in all respects satisfactory. However, one seems so promising that I propose to try it this year. It is a boom of logs of timber, to float on the water and extend from the end of the annicut up the river, a little inclined to the bank, and about 1,000 feet long, so as to cut off the lock and sluices from the rest of the river. It will be fixed at both ends to upright posts by iron-rings, to admit of its rising and falling with the water: the drift striking against this will be conducted over the annicut. This will cost, so far as we can at present calculate, about 3,000 rupees. The other evil of these sluices is that the shutters are not sufficiently manageable: they are very large, and with a heavy head of water, they require so much force to drive them down as to endanger the shutters Captain Hutchinson has planned an apparatus which, upon a partial trial, promises well, and I purpose making a more complete one. I also think of dividing some of the vents of the head sluice, so as to render them more manageable by that means. These alterations will not be expensive.

"*4th.*—The Dowlaisweram branch of the annicut with its wing-walls.—This work was first built to the height of nine feet in 1848; and the water went over it while the people were still at work on it. Owing to the excellence of the chunam, however, it received no injury till the great flood at the end of the monsoon of that year; when the water got under the front-wall of the work so freely as to press against the under surface of the masonry of the top and slope of the annicut; and this blew it up. This was only for a short distance near the western wing-wall; and it was owing to the embankment having been carried too far into the river. This was certainly a mistake; but it was necessary to make every effort to complete this great length of dam, 1,600 yards, before the monsoon; and this point was gained by shortening the masonry and lengthening the earthen embankment. But in the great flood, the water scoured along the front of the work so violently as to cut away the sand from the wall and get under it too freely. The front-wall however was not undermined or breached. In the following year this end of the annicut was extended 200 yards, which completely remedied the evil. This branch has since been covered with cut-stone, making it 12 feet high. The section given to it has answered very well; and, excepting at the end near the wing-wall, there has been no injury to the work. The rough-stone apron has sunk, but not very much, and has been raised and extended. During the last monsoon I cannot perceive that it has undergone the least change; but still I propose throwing in a small quantity of additional rough stone for greater security. This branch has however one defect: from the vast quantity of stone required for covering it, and the gradual deterioration of the quarry preventing its due selection, a great deal of the cut-stone is evidently too soft, and wears under the friction of the sand and gravel passing over it. Last year a great number of the soft stones were replaced with harder ones; and it has not worn so much this year; so that it is not necessary to replace any.

CSL

The soft stones should however be gradually all removed. This does not in the least affect the stability of the work. The wing-walls are in good order.

"*5th.*—The embankment across Peetcheka Lunka is in good order; but I propose to widen it four yards. It is now six yards broad at the top. It seems advisable to do this, both to render it more convenient as a road, and also to make it more secure from the heavy sea to which it is exposed, when a high fresh is accompanied by a storm.

"*6th.*—Rallee branch with its wing-walls.—This is where the great breaches occurred repeatedly in the first rough-stone dams thrown across, to retain the water for navigation in the bed of the river. Where these breaches occurred, holes were cut by the water from 20 to 30 feet deep, which were again filled with loose-stone. It is very remarkable that this is the only part of the foundations that has caused any trouble. Where the work rested on sand it stood well; but these deep rough-stone foundations allow the water to pass through in large quantities; and repeatedly we have found, from moisture appearing in the joints of the masonry, and from heavy jets of water, a foot or more high, appearing through the rough-stone apron, that the water was pressing against the under side of the masonry of the annicut; though from its great thickness in its finished state, it can resist the pressure effectually. When first this branch was built, the rough-stone which had been thrown into the breaches was not carried up to the point where the solid masonry commenced; but it was covered with some feet of sand washed in with water, and the masonry laid on that. It is to be observed that the masonry of all the rest of the annicut is laid on sand between the front and rear retaining walls; but in other parts it cannot be washed away. Here the water passed through the stones under the front-wall and carried the sand under the masonry away. The consequence of this was, that the masonry in these places cracked, and in one spot sank till it rested on the rough-stone. When the work was examined, it was found to be hollow underneath for a considerable distance. This is very instructive. There is no better foundation for masonry than sand, if it is secured from currents of water; it is indestructible and incompressible, and so far is just as good as rock; but in situations where currents of water can get at it, as it is not like rock immovable, it is the worst of all foundations. All the part of the work thus undermined was broken up, and the masonry laid solid on the rough-stone: still this did not prevent the water passing under the work as before. A heavy bank of clay was thrown in front of the annicut last year, so as to cover the whole of the loose-stone, and this stopped the leaks at the time; but they appeared again this year, and the water spouted through the rough-stone apron strongly. We have now covered the front of the rough-stone with a heavy bank of the tough clay mixed with chippings of stone from the spoil heaps in the quarry; and the leaks seem effectually stopped. I am of opinion, however, that it would have been better to have mixed the quarry clay with the lunka earth, as it would have made it more perfectly water-tight. The work does not appear at all endangered by these leaks. This work has been completed with a cut-stone covering, which is not much worn, partly because there was time to select the stone more, and partly, I believe, because as yet less sand and gravel have passed over it than over the Dowlaisweram branch.

"*7th.*—Under sluices.—This work was undermined and ruined in 1850. I was not here when this occurred, and do not clearly understand how it happened; but it was perhaps owing to the front apron being too narrow, and the eddying of the water in front of the vents scooping out the clay to the bottom of the wells on which the work rests. Yet the width of apron was the same as at the Dowlaisweram under sluices. However, in rebuilding them we took the precautions of making both front and rear aprons wider, and of putting a double row of wells under the front retaining wall; this work is in perfect order. The rough-stone apron has sunk repeatedly, and taken an immense quantity of rough-stone as at Dowlaisweram; but it is probably now nearly settled.

CSL

"*8th.*—Rallee lock; in perfect order; has had no repairs.

"*9th.*—Head sluice the same.

"*10th.*—Rallee embankment; requires to be widened as the Peetcheka Lunka one.

"*11th.*—Muddoor branch and wing-walls.—This work was in a half-finished state when the fresh came down in 1848, and was then breached. It was completed to 10½ feet high in 1849, and since then has received no injury. This year, it has been covered with cyclopean work, instead of cut-stone, like the others, chiefly on account of its being harder. The parts covered with cut-stone had required repairs, owing to the stone-wearing, while those in which the rough rubble masonry had been unprotected received no injury. The cyclopean work is also not more than half the cost of cut-stone. This work is just now being finished, excepting the front yard, which I have left, to receive the iron posts which it is proposed to place along the whole annicut. The channel of the river below this branch was formerly very shallow; but it has gradually deepened, and is now nearly at its proper level. The rough-stone apron will require to be somewhat strengthened, consequent upon raising the work.

"*12th.*—Muddoor Lunka embankment, the same as the others.

"*13th.*—Vijaiswaram branch.—This branch of the river was two feet deeper than the Dowlaisweram one; so that the work was in fact two feet higher, causing a much more powerful overfall. The annicut was built in 1849; and on the freshes passing over it in 1850, the rough apron sunk so much as to cause some alarm for the work. A large additional quantity of stone was, however, promptly thrown in, during a very short interval which providentially occurred after the first fresh; and the work continued in that state through the monsoon. The great overfall had caused a deepening of the channel below; and this of course tended again to increase the overfall. To diminish the fall, it was proposed to lengthen the work 400 yards; but in consequence of there being no power in this Presidency to order even an urgent work of this sort, the matter was referred to Bengal, where, as usual, so much time was lost, that the sanction arrived too late, and the Government here ordered the work not to be executed. Fully expecting this course of events, I had, with the help of the money sanctioned as an advance by this Government, had everything I could think of done to secure the work without extending it. A very strong rough-stone apron was laid by Captain Orr, of a great breadth, packed and secured in every way; and the result was entirely satisfactory: not a stone was moved, and not the least alarm occurred through the monsoon. The difference of the level of the upper water and the lower bed, when no water passes over the annicut, is now nearly 16 feet; making the force of the overfall here more than double what it is in the Dowlaisweram branch. This work has been covered with cut-stone, excepting the slope at the western end, which was left, in the expectation of that part being broken up, if the work were extended. The covering of this is provided for in this year's estimate. This work will be exposed to a still more severe trial this year, in consequence of raising the Muddoor branch one and-a-half feet, which will be equivalent to raising this branch half a foot. I am not however afraid of it, but shall take the precaution to add some rough-stone to the apron.

"*14th.*—Vijaiswaram Lunka embankment, the same as the others.

"*15th.*—Under sluice.—This work, in consequence of its being out of the bed of the main river, and having a long narrow channel leading to and from it, has never been exposed to any trial like the others. The channel below, also, passes over such tough clay that the water can scarcely touch it, whatever velocity it has. The rough-stone apron has never sunk at all. The floor of this sluice has never been covered with cut-stone: this should be done when time can be found for it. Last monsoon, a loaded stone-boat got adrift, and struck heavily upon one of the small cut-stone piers of this sluice and dislodged some stones, which will now be replaced.

CSL

"*16th.*—Head sluice.—This work is in good order; but by some oversight, the main piers, which are built of brick, were not provided with stone grooves for the shutters, in consequence of which they got chipped. The first time the channel is closed for any purpose, grooved stones ought to be let into the brickwork.

"*17th.*—Vijaiswaram lock.—In perfect order, and has received no repairs. The sluices in the gates of all these locks are disproportionately small; and they take a long time to fill and empty, which will be a great disadvantage when the high level channels are completed, and there is much passenger traffic: they can easily be enlarged, and they should be, as soon as an opportunity offers. Perhaps we may be able to do it this year. I allow in the estimate for any small things of this sort that may be found practicable this year.

"The channel leading to this sluice and lock is not sufficiently capacious: if a small cut is made, it can easily be enlarged by opening the under sluices, and causing a strong scour through it.

"3. The total ordinary estimate for this year, allowing for 20,000 tons of rough-stone for the apron, and the several things already mentioned, and some others, amounts to Rs. 33,835-6-0.

"4. It should be particularly observed, that out of this, nothing excepting the repair of the trifling injury to the Vijaiswaram under sluice, is properly repairs. Throughout the whole work not a rupee is required to repair damage sustained by the work last year. Only a quantity of stone had to be thrown into the apron of the Vijaiswaram under sluice during the monsoon. This state of things is to me highly satisfactory. It seems to give a fair prospect of the actual cost of keeping the work itself in order being very insignificant. The alterations and additions proposed this year are all such as would not occur again; and they only amount to three and-a-half per cent. upon the total cost of the work. There is certainly every prospect that, including every alteration and improvement that can be thought of hereafter, the permanent annual expenditure on it will not be two per cent. upon the cost. One part of the work has now stood four monsoons, and in one of them an unprecedented flood; and I think we may thus consider the annicut as fairly established. It is also to be considered, that a work like this is not like a bridge or a building, which is liable to be utterly destroyed. Almost the worst that could happen to it would be a breach of 50 or 100 yards, which could be repaired for 10 or 20,000 rupees; a trifle in comparison of the first cost. It is also observable, that no alteration has been made in the original section of the work, excepting that the rough-stone apron has been enlarged. The Dowlaisweram branch is just as originally planned, and no alteration of any consequence has been made in the others. I must, however, say, that here as in the Colleroon, I would now prefer building a work with a vertical fall, as safer in a sandy river; and so I would in any place excepting one similar to the Kistnah, where there is an unlimited supply of stone at very low rates, and where consequently 20 cubic yards of rough-stone could be obtained at the same cost as one of cut-stone. When I planned the Colleroon annicut, I considered that the great point in these rivers was to break the force of the water effectually, and prevent it scouring the lower channel; and what I have here seen makes me think still more of the importance of that principle. But I believe, where stone can be obtained very cheaply, a large mass of rough-stone, with a very long slope on the lower side, will be the cheapest and safest work in a sandy river.

"5. Can we see this large and important work, calculated so substantially to promote the real comfort of a million of people, thus brought to completion through so many difficulties and contingencies, without heartily acknowledging the goodness of God, in thus prospering us and bringing the project so far to a successful issue, notwithstanding the opposition it has experienced from quarters from which I had every right and every reason to hope for, and from which I did confidently expect, most cordial and energetic support in carrying out a work

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of such unequalled magnitude in India (excepting that now on hand in the North-West), a work approved and ordered by the Home authorities, and calculated to be in every way so vast a public benefit? May we not hope that its accomplishment, with the abundant effects which have already resulted from it to the district, will lead to the adoption of such extensive works for the improvement of the country, and the promotion of the welfare of the people intrusted to our care, as will lead to an increasing appreciation of a Christian Government? There is nothing that the natives more thoroughly appreciate, after peace, than public works, and especially those that furnish them with water. And I cannot but trust that this is only the beginning of a series of works worthy of our nation, our knowledge, our religion, and the extraordinary power God has been pleased to put into our hands. I say our religion; because I am sure it ought to lead us to do our utmost in every way to care for those who are thus committed to us.

"6. It remains for me to speak of the state of the bed of the river about the annicut, which will require to be carefully watched. When the work was commenced, the passage of the water to the Muddoor and Rallee branches was very much obstructed by the large Island of Waddevanee Lunka, and its adjacent sand banks; so that in low freshes the water reached those branches by very circuitous routes on both sides. There was then a complete channel between the head of the delta proper, and the same Waddevanee Lunka. Great changes have now taken place hereabout. A clear and broad channel has formed close to the western side of that lunka, leading direct to the Muddoor branch; and another is rapidly forming on the east side, leading direct to the Rallee branch, while the sand has accumulated between the head of the delta and the lunka; so that, in another season or two, it seems evident that the head of the lunka will, in fact, be the head of the delta, nearly three miles above its former head, and above the line of the annicut; while the water will flow in a clear and direct channel to every branch of the Annicut. This is a desirable state of things; and had not the river shown such decided symptoms of accomplishing it without help, it would have been well to have assisted it. There are however banks forming which require to be removed. The principal one is opposite to the eastern end of the Vijaiswaram branch, which, if left to itself, would extend and throw the stream upon the western wing-wall of the annicut. In the lawless state of these districts, it has been customary for the inhabitants of the villages near the river, whenever a bank began to form and threaten mischief to the opposite bank of the river, to hasten the evil prodigiously, by planting the sand with durbah grass, which rapidly increases it; and it speedily becomes a high and solid lunka. The object of this is to form new tobacco land; but, of course, it is done at the expense of the land on the adjoining bank of the river, which is cut away proportionately; and not only so, but every deviation from a direct course thus produced tends to cause a series of sets on the alternate banks of the river below. All this ought never be tolerated in a civilized community: I wrote about it to the Collector some years ago, but it is not yet quite stopped; and even here, under our own eyes, and endangering the annicut, they have been planting the newly formed banks. This is, however, in the Masulipatam district. Wherever such banks form, and tend to throw the current upon the bank of the river, not only ought grass not to be planted, but if it grows naturally, it must be rooted up, and, if necessary, channels cut through the bank to facilitate its dissolution by the current. This is always done in the Cauvery. It is especially necessary in the neighbourhood of the annicut; and if not done, the river would inevitably set on one or other wing-wall, and cut away the adjoining lunka, till it go round the masonry. I have provided for rooting up the grass, and cutting channels through two newly formed banks this year. In the first years, in consequence of the indirect course of the stream, the heads of Peetcheka Lunka and Muddoor Lunka were rapidly cut away, and it became necessary to protect them by loose-stone work; but in consequence of the changes above mentioned, this danger has now ceased. There is rather a set upon the bank near the village of Dowlais-

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weram, and it may be necessary to protect it by loose-stone groins; but at present the action of the water there is not serious. Below the annicut, there is, in a certain state of the river, a strong set on the Dowlaisweram bank; but several groins have been thrown out there, and it seems now pretty well protected. Some additional stone may however be required there. It must be observed that these changes, from the action of the river on its banks, are much slower in the Godavery than in the Colleroon and Cauvery, and as it seems also in the Indus and Ganges; so that there is plenty of time to take the necessary precautions; and the stone we have here at hand is a material for barriers far beyond the power of the stream to remove, even though in pieces of the size of the first. In comparing the present state of the river with the map constructed thirty years ago, it will be seen how very slowly the encroachments of this river proceed.

"7. The Muddoor branch being now covered, and the extension of the Vijaiswaram branch given up, the only work remaining to complete the annicut is the line of iron posts and planks along the front, the estimate for which has been sent to Bengal. I am now taking the opportunity of covering the Muddoor branch to place the posts along it.

"8. The rough-stone apron of the annicut throughout seems to be well established: there is no appearance of any sinking or disturbance of any consequence this year in any part. It is generally from 15 to 20 yards broad. I am now however throwing in additional stone, according to this year's ordinary estimate, strengthening each branch according to the proportionate force of the water over it. To the Muddoor branch, as it is now higher than it has been hitherto, I purpose adding considerably, and also to the Vijaiswaram branch, which ought to have an abundantly large apron. The apron laid by Captain Orr, last year, stood most perfectly; but we can hardly take too much precaution on this point, especially as the cost of rough-stone is so moderate.

"9. I have now the honor to request that the establishment which I have recommended for the conservation of this important work may, if approved, be appointed without loss of time. A body of thoroughly trained men, under efficient superintendence, permanently resident on each portion of the work is essential, and should be immediately appointed, and housed; that they may be fully prepared for their duties before the freshes. No water works of any kind can ever be trusted to take care of themselves; but especially those in a delta require the most vigilant care; and both the cost of this work, and the vast amount of property dependent upon it demand that no risk should be run about it. I trust that, whatever is decided as to precise arrangement of the superintendence of this system of works, authority may be granted for entertaining at once those that are required for the annicut and other works already executed, as a temporary arrangement."

The order of Government on receipt of the above was as follows:—

"1. The Right Honorable the Governor in Council has received with much satisfaction the report of Colonel Cotton on the state of the Godavery Annicut, which may now be said to have arrived at completion, through the unceasing exertion and energy of Colonel Cotton and the officers associated with him in this great undertaking.

"2. It must be a highly gratifying termination of Colonel Cotton's immediate connection with the first division, that he should have been enabled to notify to Government the complete stability of the annicut, and the success which has up to this period attended his plans; and in congratulating that officer on these happy results, the Governor in Council has much pleasure in recording his obligations to Colonel Cotton, Captain Orr, and the officers of the department under their orders, for their services on this occasion; and it will be his agreeable duty to bring the same to the notice of the Honorable the Court of Directors.

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"3. The Right Honorable the Governor in Council has not failed to remember the very valuable aid rendered by Mr. Forbes, late Sub-Collector of Rajahmundry, during the progress of the work. By the vigorous execution of the responsible duty assigned to him, the constant requirements of the Engineer department were supplied; and by his judicious arrangements, order and regularity were preserved among the vast assemblage of artizans and labourers congregated at Dowlaisweram."

In this 'order' only the 'officers' connected with the work are referred to, but the commendations bestowed on them might well have been extended to the many subordinates who had also shown 'unceasing exertion and energy.' Pre-eminent amongst them was a native overseer named 'Veenem Veranah' who seems to have been gifted with exceptional qualifications for conducting engineering operations as well as for directing and managing large bodies of native labour. Of him Colonel A. Cotton thus wrote*: "I cannot say less than that if we had not found a native of his remarkable qualifications, considering the state of the district when the works were commenced, I do not see how they could have been executed, for no European could have supplied his place, and no native at all equal to him has appeared." He was made a Sub-Engineer with the title of 'Rai Bahadur' and continued for many years to render excellent service in connection with the great work to the successful accomplishment of which he had so largely contributed. On one of its walls there is a tablet bearing the following inscription:—

V. VERANAH GARU
Rai Bahadur
SUB-ENGINEER, D.P.W.
Obiit Oct^{r} 1867.

Soon after the completion of the anicut, Colonel Arthur Cotton became Chief Engineer of the Presidency and the charge of the Gódávari works was assumed by his brother Major (now General) F. C. Cotton, Captain Orr, who had been the Chief Executive Officer in their construction, having gone to carry out the Kistna Anicut.

This brings us to a well-marked period in the general history of the Gódávari works.

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* His memorandum, dated 19th January 1858.

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Photographed by Messrs. Nicholas & Co. Madras.

DOWLAISHVERAM ANICUT F

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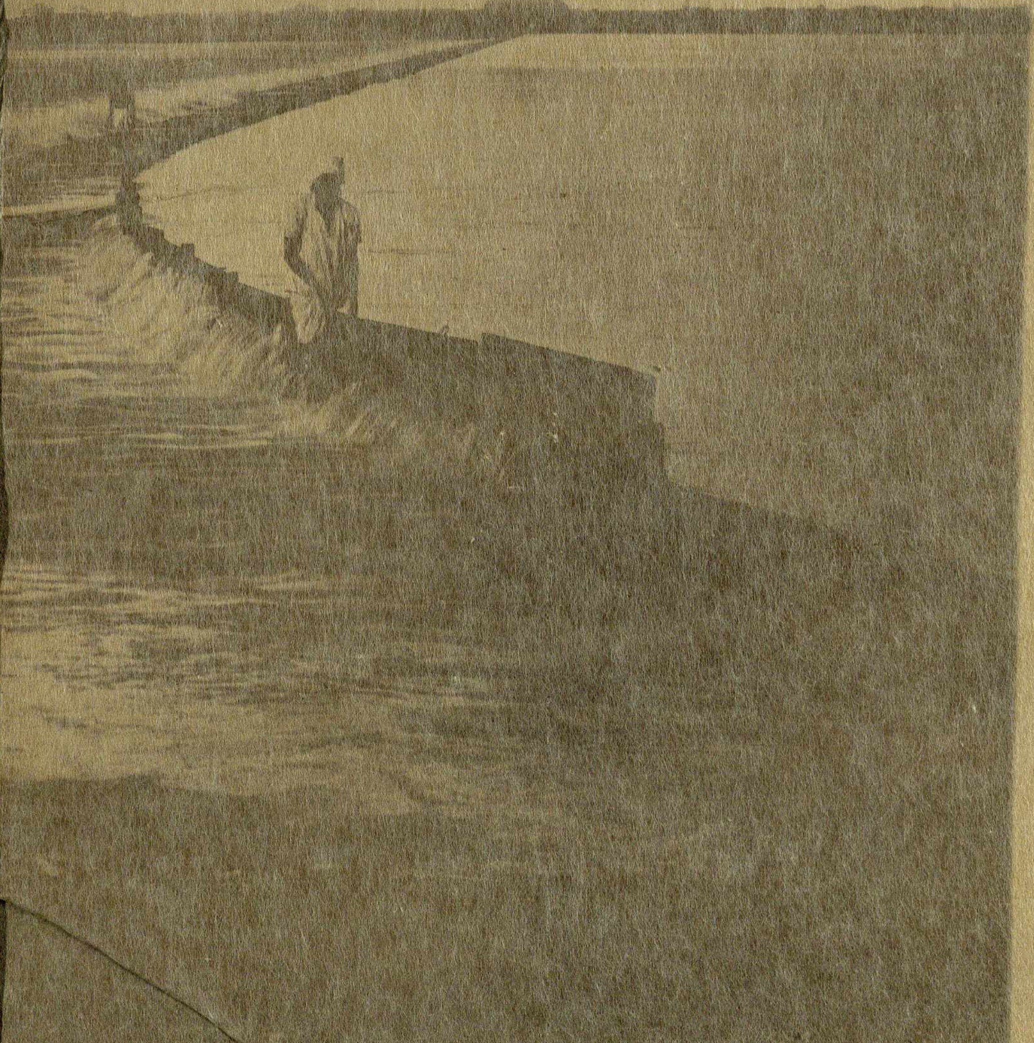

Photo-Print Survey Office, Madras
1895

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CHAPTER V.

ALTERATIONS IN THE ANICUT AND HEAD WORKS AFTER THEIR ORIGINAL CONSTRUCTION.

From time to time since the Anicut and Head Works were first declared completed, alterations have been made in them, and it is thought that it will tend to clearness of narrative if some account of the changes and of the circumstances attending them, be given immediately following the chapter which has dealt with the original construction of those works, instead of being dispersed about various parts of this History.

Alterations in the Anicut.

The changes as regards the Anicut itself have been the constant additions to the rough-stone aprons and talus, mentioned in Chapter III, and the *raising of its crest.* Even before the work was finished, in 1852, it was seen that its height was insufficient to always secure an adequate supply of water to the canals, and an estimate was sanctioned for fixing along its crest, at intervals of 8 feet, cast-iron grooved posts, between which horizontal planks could be placed, after the river had fallen low and the season for floods was over, to then hold up the water for an extra 2 feet. This work cost Rs. 25,363. But even the extra command thus obtained was found insufficient to meet the requirements of the rapidly increasing irrigation and navigation, and ten years later it was decided to raise the Anicut, in masonry, by 2 feet. This work was carried out between 1862 and 1867 at a cost of nearly 3 lakhs * of rupees. On the new crest were replaced the arrangements above described for at times holding up the water an extra 2 feet.

Another raising of the Anicut by 2 feet, with cut-stone and concrete, is now in contemplation.

Breach in Anicut, 1857.

The only serious accident to the Anicut itself happened in 1857, and though it did not entail any important alteration to that work, this seems a convenient place in which to give some account of it and of the way it was dealt with.

On the 14th November of that year, when the season for floods was over and the river had fallen to but little above the crest of the Anicut, the Eastern end of the Maddúr branch of the work suddenly subsided into a deep scour-hole below it, and a clean breach was formed, through which the river poured with such great depth and volume that it was impossible to attempt to stop it at the place.

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* Narrative of the Gódávari Delta system, para. 14.

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Captain (now General) F. H. Rundall, R.E., then District Engineer of the Gódávari, decided to prevent the access of water to the whole Maddúr branch by a dam "*400 yards above the line of the Anicut where I found "the shallowest water obliquely across the river and measuring about 600 "yards." After working at this for more than a month, however, it had to be abandoned for, though it was more than once believed to be all but completed, it breached just as the final gap in it was being closed. Colonel Arthur Cotton, who visited the work at the time, then recommended a new site for the dam some distance further up the river, and a different method of constructing it. Captain Rundall thus gives a condensed account of the operations in his letter to the Chief Engineer, No. 860, dated 21st January 1858 (with P.M.G. No. 468, dated 15th March 1858) :—

"16th. The method adopted for stopping the breach was as follows.

"17th. A site was selected about half a mile above the anicut where the deepest place of the river was only 10 feet and the line run obliquely across so as to obtain a greater length of discharge while the Dam was under construction.

"18th. Trusses, commonly called 'Horses' in this country, were fixed as far as the strength of the current would admit, and then stones thrown in against them, along the shallowest part of the river for about 200 yards, the sand bank was commenced at once, while the remaining 350 yards was lined regularly throughout with stone. In about 20 days after the accident the whole length was thoroughly well lined, and the level of the water considerably raised, so that I was sanguine of bringing the whole up to a regular height, and thus of raising the Dam faster than the basin above could be filled. For this purpose I worked day and night, but just as I looked for success the head of water became too great for the size of stone we had at command, and the Dam was breached at the centre. The difficulty of obtaining a sufficient supply of large stone and of handling what we were able to procure, led me to adopt the use of cradles made of interlaced bamboos in the shape of a sap roller and of a size so that when full they should weigh from 3½ to 5 tons. The result of these cradles was perfectly successful and the Dam would, as reported in my letter of the 28th Ultimo, have been closed in 3 days, but for an occurrence which I had not foreseen and which it was impossible to remedy. This was the formation of a violent eddy in rear of the sand bank immediately adjoining that part of the Dam which was now being finished. This whirlpool increased in violence and depth until it undermined the bank and so occasioned a breach of 40 yards. After this greatly discouraging occurrence when there remained but 15 yards of the Dam to finish with an average depth of 10 feet, Colonel Cotton suggested my choosing another site and adopting his method of not attempting to stop any portion of the water-way with sand until the Stone Dam was raised above the water the whole way.

"19th. I accordingly set to work the following day. The river which had greatly fallen meantime was nowhere more than 7 feet deep. The length as before about 500 yards and the volume of water passing not more than one-half what it was when we first commenced though considerably more than either Colonel Cotton or myself calculated. This second Dam was across the river in a week; the whole was done with the baskets, 20 boats being discharged together on a line at one and the same time and as all parts of the Dam rose simultaneously or nearly so, there never was the same trouble with the boats as previously. The difficulty though subdued, was not entirely overcome, for the river did not as anticipated remain at the level which it was thought the discharge through the under-sluices would preserve it, but it continued to rise as much as 3 inches a day. The action of the water in such works is to increase the depth immediately at and above the Dam by scouring the sand from under the stones; while the spaces unavoidably

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* His letter, dated 12th December 1857, with P.M.G., No. 143, dated 26th January 1858.

GSL

left between the baskets doubtless increased this to a certain extent, so that the stones always sunk during the night and the depth of water going over them being increased, the top ones were rolled off from time to time and so every day there were threatenings of breaches, which however were always averted by the timely application of the never failing baskets. The 'constant failures' alluded to in your Proceedings of the 7th Instant were not properly such. There was but one absolute failure, viz., that mentioned above, but it is not possible for any one, professional or non-professional, to understand the difficulty and thousand contingencies that are liable to occur (especially when the difference of level between the water amounts to 10 feet as it did at the last in this Dam) who have not themselves ever witnessed the closing of a breach in a river when 1¼ million cubic yards per hour, 9,370 cubic feet per second, are being discharged. When the stone Dam was fairly in advance of the rising of the river the sand bank in front was commenced, and this as reported was finished on the 6th Instant. Water is now flowing over the annicut a few inches deep only, as the Dowlaishweram under-sluices are still open and discharging 1 million cubic yards per hour."

As soon as the dam was finished, the repair of the Anicut itself was taken in hand. The cost of the operations is thus stated in Captain Rundall's memorandum of 28th April 1858 (with P.M.G., No. 1210, dated 26th June 1858):—

"The cost of the temporary dam after deducting the amount of stone recovered was Rs. 30,365.

"The repairs to the Anicut itself will, when the cut-stone work has been completed, be Rs. 26,290." . . . .

The principal changes in the other 'Head Works' have in most cases resulted from failure of the original works; of them there now remain only one of the Head Sluices and the three Under Sluices, and they have been added to and, to some extent, altered.

Destruction of Vizéswaram Head Lock and construction of two subsequent Locks.

The first of the Head Works to go, was the **VIZÉSWARAM HEAD LOCK,** which had but a short life as it was destroyed in the floods of 1852. It had been built immediately adjoining the right flank of the Western Delta Head Sluices with one of its chamber walls in the waterway of the approach channel, unbacked by earth, and it was this wall apparently which failed. Colonel Arthur Cotton (then Chief Engineer) thus refers to this accident in his Inspection Report of 23rd February 1853:—

"The first work to be noticed is the new lock at Vijaiswaram. This work is rapidly advancing, and promises to be completed in time for the freshes. The failure of the old lock seems to have been partly owing to the use of imperfectly burnt bricks. The side-wall fell, though the pressure of the water at the time was certainly under what, according to the rules observed in such cases, should have been necessary to breach it, that is to say, the thickness of the wall, at the point where it yielded, was much more than one-third of the height of water it had to withstand; which, situated as the lock was, was certainly ample, according to calculation and to my experience. It had been built four years, and the chunam was excellent. At the point where it broke off the bricks were very bad, and no doubt they were partly the cause of the failure; but still I cannot fully account for it. A considerable body of water passed through the lock after the failure, and helped to flood the country below; but all that could thus pass through an opening 15 feet wide was a trifle compared with what would have passed into the delta on this side, had this and the new Apparow channels been without head sluices, as formerly, and had there been no river bank from Kakarapurroo to the hills, a distance of 36 miles. In fact before these works were executed,

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had such a flood occurred, almost the whole crop on this side of the delta would have been destroyed; and a loss of many lacs would undoubtedly have been sustained. I should think remissions of revenue to the extent of two or three lacs must have been made. Instead of this, I am informed by the Collector, that the revenue of this year will exceed by at least 20,000 that of last, which again was 1,06,000 rupees above the preceding. What stronger proof could be given of the effects of these works already, than this, that in a season of most severe flood, when a greatl oss would certainly have been sustained in the former exposed state of the district, there is still an actual increase upon a previous rapidly augmenting revenue? We have thus a clear proof of the tendency of the works to counteract the irregularity of the seasons, so far as excess of water is concerned."

It was decided not to rebuild the Lock on its former site, a most dangerous one for boats using the work, but to place it "in * a more convenient situation sufficiently remote from the of draft the sluices and not exposed to accident from the extraordinary pressure of water which overthrew part of the former structure."

The estimate, submitted in November 1852, for the Lock and bridge over its tail-bay, was Rs. 17,876. Its actual cost appears to have been Rs. 32,638. This large excess is doubtless partly due to the fact that whilst the work was in progress, Colonel Cotton ordered the size of its chamber to be made † 150′ × 15′ instead of 100′ × 15′. With reference to this change, he says in his Inspection Report above quoted from :—

"I also requested the Civil Engineer to take the opportunity of the erection of the new lock to lengthen it 50 feet, making it 150 feet by 15. The proofs we have now had of the extraordinary cheapness of inland steam navigation in this country, supported by the great results obtained in the St. Lawrence canals, and under the United States, has impressed me more than ever with the suitableness of this means of transport to this country, and of the immense importance of so constructing our channels, that steamers of considerable tonnage can traverse them. As no locks have yet been built on the line from the Godavery towards Madras, it seemed a very great point to secure the present opportunity for providing for an effective system. With screw steamers of 150 feet by 15, and drawing five or six feet water, not only may a wonderfully cheap transit be secured, but a very good speed also. Such vessels (but drawing only two or three feet in the dry season) would, when the line of canal is completed, proceed from Madras to within 80 miles of Nagpoor, thus throwing open a very large portion of the whole Presidency, at a rate of transit such as has not yet been thought of in the country. Such a steamer could carry 200 tons, at five miles an hour, and at a cost of two annas a mile. The lengthening of the locks will add but little to their cost, as the gates, sluices, wing-walls, &c., will remain the same. All the locks along the great northern line in connection with the annicut should be made the same. Beyond the Godavery, however, is of less consequence, because no large tract of country to the northward can ever be connected with Madras as its main line of trade."

The new work was built in 1853 and still stands. It has however been converted into sluices, as it was found advisable to build a new and larger Lock even further away from the Head Sluices. This newest Lock is a double one with chambers 150′ × 20′, the general design being that of the new Dowlaishweram † Head Lock,—to be noticed further on,—but the means of filling and emptying are side culverts instead of gate valves.

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* Para. 1 of letter, No. 776, dated 25th November 1852, from Secretary, Board of Revenue, to Chief Secretary to Government.

† *See* plan in Atlas Volume.

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The work bears the following inscription :—

> This Lock was constructed
> under the supervision and management
> of
> D. Ramana Naidu, Anicut Superintendent,
> Messrs. J. Inglis, Assistant Engineer,
> C. Mitford Smith, Executive Engineer,
> G. D. Wybrow, Supg. Engr., 1st Circle,
> and was opened for traffic on
> *5th December* 1891
> by
> G. T. Walch, Esqr., Chief Engr. for Irrigation.

Vizéswaram, Western Delta, Head Sluices.

The destruction of the first Lock, in 1852, no doubt injuriously affected the adjoining Head Sluices, and they could not withstand the floods of the next year. Major F. C. Cotton thus reports their destruction in his letter to the Board of Revenue, dated 29th August 1853 :—

"4. At Vizéswaram the Head Sluice which suffered from the fall of the Lock wall last year has been destroyed. This accident seems to have been caused by the extension of the injury that occurred when the Lock was ruined and which must have been greater than we supposed ; a slight crack was perceptible in the front wall of the Head Sluice then, but our examination of the aprons led us to hope that the foundations were uninjured. . . . Mr. Chambers, who was at Vizéswaram the morning before the accident and the evening after it occurred . . . . thinks that there is no doubt that the foundation was undermined last year and that the apron was blown up, when the head of water was too great. He states that there was 10 feet of water in the Apparow '(*i.e.*, in rear of) the sluice' and 29 feet 3 inches above '(*i.e.*, in front of) the sluice when this occurred.' . . . .

"9. Till the September fresh has passed, there is no use in my making any proposals for the restoration of the sluice, half of which still stands, but it is so injured that if it is does not fall, it must be taken down.

"10. The foundations of the southern portion may be of use again, but I think it probable, that it will be thought advisable to build an entirely new work."

The new work was built in the following year, and still exists though it has been altered to some extent, especially as regards its means of regulation. These are now similar to the shutters and gearing of the new Central Delta Head Sluices ; drawing of which will be found in the Atlas Volume.

Destruction of Central Delta Head Sluices and construction of new ones.

A quarter of a century now passed before the failure of another of the old Head Works ; then, on 16th August 1878, the Central Delta Head Sluices collapsed. The river at the time was 10 feet over the Anicut or 16 feet above the sluice floor ; the water in the canal having been reduced below full-supply level on account of rains in the delta, the head of water against the sluice was about 11 feet ; this however was much less than it had often been before, and 2½ feet less than it had been only eleven days previously. The influx of water through the gap in the ruined sluices was, of course, very great ; this it was necessary to stop without delay, to prevent as far as possible damage to crops and injury to the various canal works. In deciding what was to be done, it had to be borne in mind that mere damming of the stream would not meet the requirements of the case, but that there must be means of passing the water, which for another four months would be wanted for the 95,000 acres, or so, of wet crops of the Central Delta—crops worth many lakhs of rupees. The overfall and rush at the site of the ruined work were too violent to allow of anything being attempted there, and it was decided to put a stone dam across the canal 725 yards from its head, where the canal was in deep cutting. To do this was no easy matter, for the river remained high, upwards of 8 feet over the Anicut, for twelve days, and the water rushed past the place with great velocity and a depth of from 15 to 20 feet. The bed of the canal was pure sand, so that it was necessary that any obstruction to the current should be deposited as uniformly as possible across the whole breadth of the channel, or the concentrated rush of water over any unprotected parts of the bed would be certain to scour them out to great depths. After trial of various ways of securing this uniformity in the deposit of the stone, the following method was adopted and proved effective: Two securely stepped and stayed masts were erected, one on either side of the canal, some little distance above the site for the dam and between these was swung an overhead wire cable with depending ropes at intervals of a few feet; to any of these ropes the stone laden boats could be fastened by the bows and gradually lowered down-stream, stern first, to the required positions for depositing the stone. So treated the boats were easily handled, which was not the case when fastened in any other way than "end on" and allowed to swing with the stream; if prevented from doing so and brought at all broadside on ot the current, they became quite unmanageable and either carried away or were swamped. These particulars are mentioned as not unlikely to be of use to those who may have to deal with somewhat similar circumstances.

More than 13,000 tons of stone and 11,000 sand bags were used in the construction of the dam. Its top part was formed of sand bags, by manipulation of which rough, but practically efficient, regulation of the supply to the delta was managed and the loss of crops was confined to that due to the inundation; this proved less than was expected, as the various surplus works, natural drainages, and breaches in the river banks, got rid of much of the excess of water and the remainder, having a large extent of country to spread over, the submergence had not, in the 15 days before the influx of water was brought under control, proved so great as to seriously injure any considerable area of crops.

The damage to the Delta *Works* was chiefly confined to breaches of canal, channel, and river, banks. Of course as long as it was necessary to keep up the dam across the main canal, *through* navigation into, and out of, the delta was impossible and transhipment had to be resorted to.

The cause of the accident was probably the insufficiency of the flooring along the up-stream face of the work, which allowed eddies, set up when the sluice was discharging under considerable head, to disturb the sand around and under the foundation wells of one of the main piers. The necessity for flooring of sufficient breadth on the *up-stream*, as well as on the *down-stream*, side of works built across sandy-bedded streams, should never be lost sight of; the Central Delta Head Sluice is by no means the only work which inattention to this necessity has brought to grief.

In designing the new Head Sluice, it was decided to depart from the custom of using foundation wells, so universal in the Madras Presidency when building on sand, and to carry the whole work on a platform of concrete, the

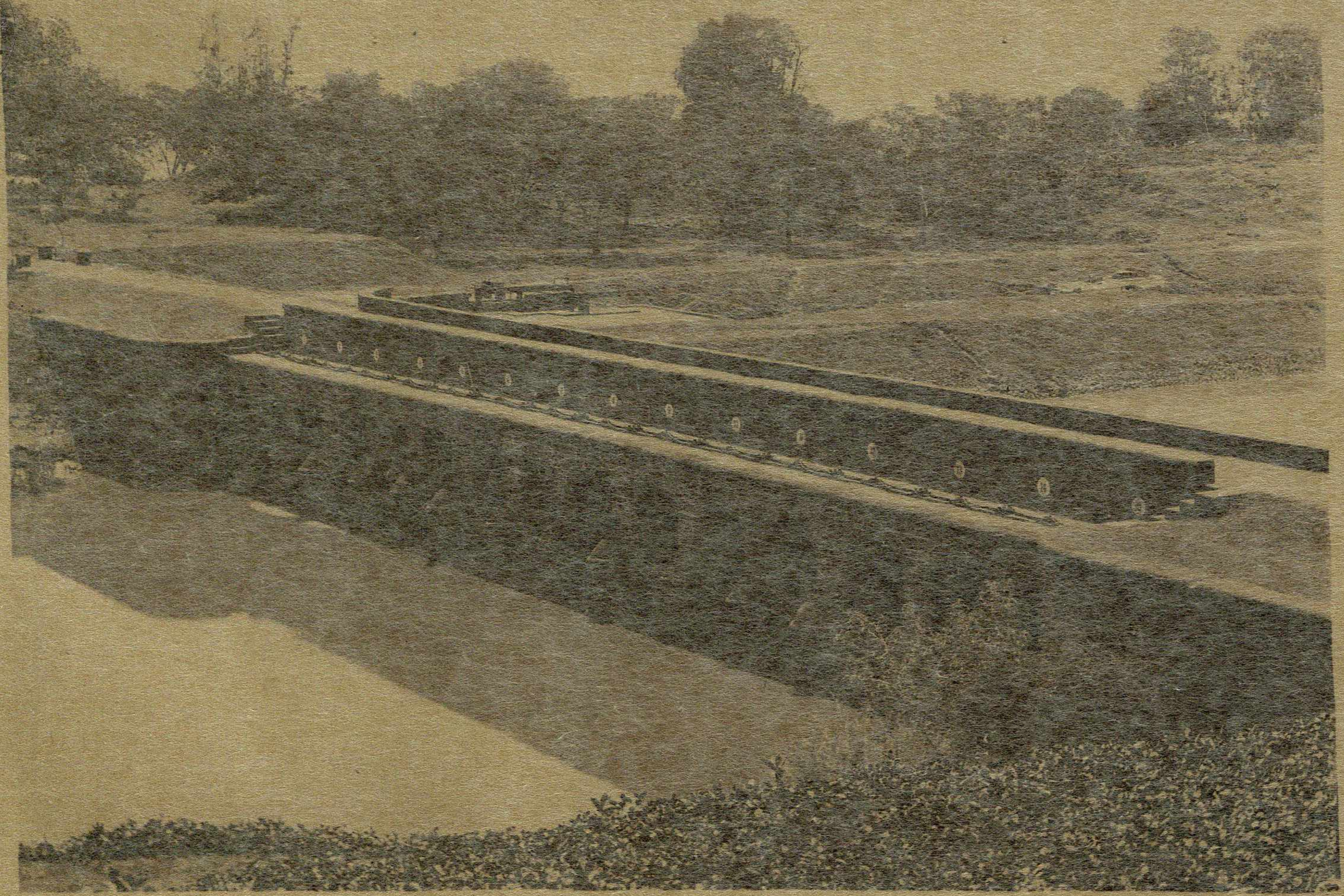

Photo.-Print Survey Office, Madras 1896.

CENTRAL DELTA HEAD SLUICES.—FRONT VIEW.

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sand under the platform being prevented from moving by deep curtain walls along the edges of the wide aprons, provided *above*, as well as below, the work. This has answered perfectly and the work, plan of which will be found in the Atlas Volume, shows no sign of settlement or crack, though in the sixteen years of its existence it has been subjected to the severe tests of the two highest floods ever known.

It was, by the unremitting energy of Mr. W. B. deWinton, so far built in the working season of 1879 as to be ready for regulating the supply to the delta during the season of freshes of that year, and the next year the arches of the bridge over it, so designed as to be really separate from the sluice part, were turned, and the whole work finished.

The view of the Sluice facing this page, is from a photograph by W. J. Howley, Esq., Assistant Engineer.

The old Sluice was worked with 'needles' or vertical baulks of timber lifted by levers and driven down by mauls; with such arrangements no nicety of regulation is possible. The new Sluices, of 15 vents 6 feet wide by 10 feet high, were fitted with shutters in three tiers worked by screw-gearing designed by Captain (now Colonel) R. R. E. Drake-Brockman, R.E. A drawing of this excellent arrangement will be found in the Atlas Volume.

Destruction of old Head Lock, Eastern Delta, and construction of new one.

The next of the original Head Works to succumb was the HEAD LOCK TO THE EASTERN DELTA, at Dowlaishweram. This was situated adjoining the left flank of the Head Sluices and projected from them up-stream, so that its right wall stood in the river unbacked by earth, just as was the case with the Vizéswaram Lock, the destruction of which has been noticed near the beginning of this chapter. Early in its existence this wall appears to have been a source of anxiety, for in 1853 Colonel F. C. Cotton writes* thus about it: "I find that a crack which has existed for some time in the Lock wall near the (Dowlaishweram) Head Sluice has extended . . . . it will be advisable to build buttresses to this wall in the dry season."

On the 19th August 1886, when the river was 14½ feet over the Anicut, this wall suddenly toppled over, carrying with it the Lock gates and leaving a gap into the canal 15 feet wide through which the water poured. During the next two days the river continued to rise till it attained the then unprecedented height of almost 17 feet over the Anicut. For some time it seemed likely that the tremendous rush of water would scour out a hole near the Head Sluices which would lead to their destruction, and this would certainly have been the case had it not been that a few years previously the Lock had been lengthened by the addition of a second chamber built on a platform of concrete; the walls of this second chamber were overthrown, but its floor and foundations remained intact and protected the bed, so that the deep scour hole did not occur till beyond the rear apron of the sluices. Their destruction, however, seemed so imminent that arrangements were promptly made for dealing with it in the way adopted in the case of the destruction of the Central Delta Head Sluices already described. Masts were fixed and stone collected for a dam about 2¼ miles down the Main Canal, where it is in laterite cutting, and has therefore a hard bottom.

The rush through the gap left by the fallen Lock was far too great to admit of stopping it by throwing in sand bags or stone, and to have

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* His letter to Secretary, Board of Revenue, dated 29th August 1853.

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attempted to put baulks of timber across the front of the gap with their ends resting against the Head Sluices would probably have led to the destruction of that work. A ‘ crate ’ of upright iron bars with wooden cross pieces strung on to them about a foot apart, was made to fit the gap between the Head Sluice abutment and the left wall of the Lock, which fortunately did not fall. This crate offered comparatively little obstruction to the current, and after the river had fallen somewhat, it was lowered into position and securely anchored up-stream ; it was then filled with sand bags and stone, and answered its purpose perfectly. It had to be retained in position for some four months till the river fell to nearly the level of full supply in the canal, and there was no fear of another fresh, during which time boats could not pass into or out of the Eastern Delta, and transhipment had to be resorted to. As showing the immense value of the through navigation dependant on the Lock, it may be mentioned that the Collector of the District stated in his letter No. 93, dated 22nd February 1888, that the failure of the work which closed the through traffic for four months “ reduced the trade of Cocanada ‘ (in 1886) ’ by about 31 lakhs.”

No time was lost in making arrangements for a new Lock in a better position, and sanction having been received to a design prepared by the Superintending Engineer, ground was broken on 20th November and the Lock was opened for traffic on the 20th of the following June, ‘ Jubilee day.’ A tablet let into the work has the following inscription :—

This Lock and River wall were built
in 1887
under the supervision and management of
Mr. J. F. Somers-Eve, Assistant Engineer.
Mr. J. E. Paul, Executive Engineer.
Mr. G. T. Walch, Suptg. Engr. of the Circle.
The Lock was opened on the
50th Anniversary of the accession
to the Throne
of
Her Most Gracious Majesty
QUEEN VICTORIA.
Empress of India.

The work was not quite finished off for some months later.

The Lock, with ‘ River-wall ’ leading to it, is a handsome work ; it has two chambers each 150′ × 20′ ; during by far the greater part of the year, it can be worked as a single lock and it then has an effective length of 300 feet, which, so great is the traffic through it, is frequently no greater than is required. A plan of the work will be found in the Atlas Volume. If that be referred to, it will be noticed that the chambers are filled and emptied by valves in the gates, and not by side culverts as is the case in all the modern locks of the system. This arose from the pressure of time in construction, and as the sills are all on the same level and the water can never fall below them, there is not the same objection to the arrangement as in the cases of *lift* locks, where the lower reach level is below that of the upper sill, and water if admitted through the front gates, pours over the sill, during part of the time of filling, in a cataract which shortens the effective length of the chamber and violently agitates the water in it.

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The gap where the destroyed lock stood, was converted into two new vents, (each 5′ wide × 10′ high) additional to the previous thirteen of the Head Sluices.

New Head Lock, Central Delta.

There now remained only one of the three original Head Locks, viz., that at the entrance to the Central Delta. It did not actually collapse, but it became so shaky that in 1889–90 it was replaced by a new one, a plan of which will be found in the Atlas Volume. The chambers of this Lock, it is a double one, are only 105′ × 15′, that being the size adopted for such works on canals of the second class, to which class belong all the canals of the Central Delta.

Eastern Delta Head Sluices.

The HEAD SLUICE TO THE EASTERN DELTA at Dowlaishweram now existing is that originally built, but it has been altered to some extent, especially as regards its means of regulation, which were the old rough arrangements of 'needles' or 'baulks,' but are now similar to those of the new Central * Delta Head Sluice referred to above. It has had two vents added to it where the old Head Lock stood, as stated when dealing with the building of the new Lock.

The three sets of Under Sluices.

The three original sets of UNDER SLUICES, though they have all been the sources of great anxiety at times, yet stand, with, however, very extensive additions to their floors and aprons and with the substitution of shutters actuated by screw-gearing, for the 'baulks' with which the vents were originally provided.

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* *See* in Atlas Volume.

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CHAPTER VI.

THE GUNNARAM AQUEDUCT.

WHILST the Anicut and Head Works were in progress, Colonel A. Cotton had been arranging for carrying the water which they would make available from the river, to various parts of the delta. Amongst the works for this purpose there was one which merits special notice on account of its importance, the nature of its design, and the rapidity of its construction. This is the 'GUNNARAM' or 'NAGGARAM' AQUEDUCT, over the Vainateyam branch of the Gódávari (*see* Chapter I). It was included in an estimate of Rs. 1,38,647 for 'Works in the Central Delta' sanctioned in February 1852 (*see* Chapter VII) and is thus referred to in Colonel Cotton's letter, dated 16th August 1851, sending in that estimate :—

"8. A large aqueduct across the small branch of the Gódávery near Gunnaram to convey the water into the Naggaram talook. This is the only large work that will be required in the delta. The estimate for it is Rs. 73,200-6-4. The plan prepared contains 39 * arches of 40 feet each. The breadth of the channel to be 15 feet so as to be just navigable for boats, with a towing path 9 feet wide on one side. It is calculated to convey 70,000 cubic yards of water per hour which is considered to be sufficient for the talook of Naggaram. By increasing the fall through it of course almost any quantity of water might be passed through it, but the breadth has been regulated by the navigation, that is, the width given to it and velocity allowed are such as will admit of its being navigated without inconvenience. This work is not a simple aqueduct, but rather a aqueduct sluice. That is, the water in floods will rise above the crowns of the arches. It is evident that it would be both very expensive and dangerous to carry the bed of the irrigating channel (above and below the aqueduct) much above the level of the country, and as the floods rise to the surface of the ground on each side, at least the thickness of the arches must be below the surface of the water in the river at such times. The work is accordingly planned as a sluice, that is, with a flooring and apron. The obstruction offered by it to the water is about the same as that of the anicut in the highest freshes, that is, the proportion of waterway to the whole section of the river at that point is about the same as the proportion the waterway over the anicut bears to the section there ; of course in ordinary freshes, before the water reaches the crowns of the arches, the obstruction will be only that of a common bridge. Thus the head of water caused by the work, and the force of the current through it will be, when it is most, that is in the highest freshes about the same as it is at the anicut when it is least. This gives us therefore a good measure of the power the water will have upon the bed of the river below. Now long before the force at the anicut is reduced to this, the power of the water upon the apron is quite insignificant. I have allowed for a front apron of yards 10 broad and a rear apron of yards 20 supported by a line of wells along its whole length with some loose stone also below them. There will be a floor of large packed stone also under the arches with a line of wells along the lower side from pier to pier. This work will be constructed within the limits of tide-water, and it will be necessary therefore to bank out the river on both sides, and the expenses connected with laying the foundation will perhaps be considerable, for which I have allowed in the estimate. The foundations must, of course,

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* Was built with 49 arches.

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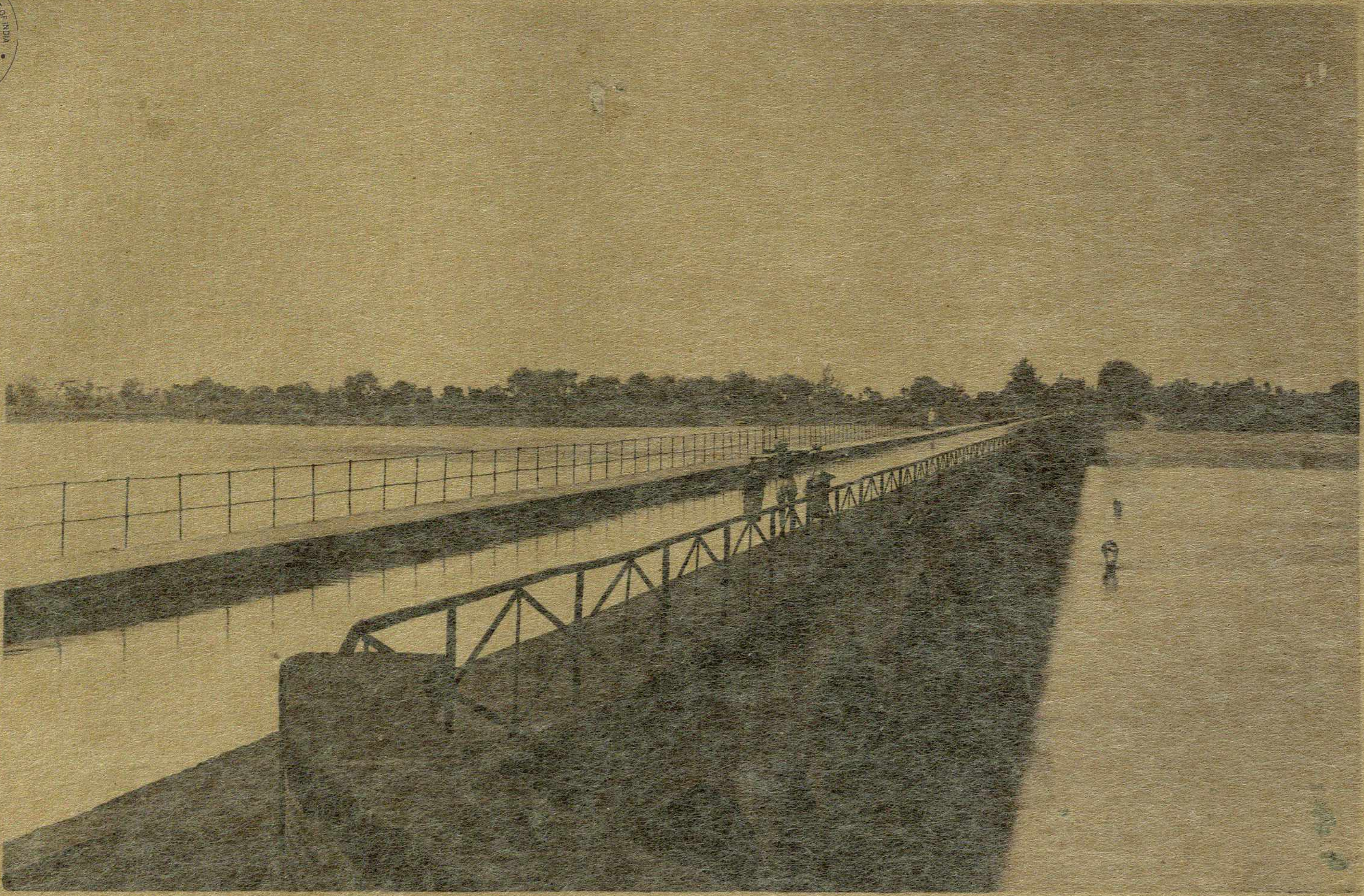

Photo.-Print Survey Office, Madras 1896.

GUNNARAM AQUEDUCT.—FROM UPPER END.

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be wells, the piers to be of bricks both as stronger than rubble masonry where the weight of arches is to be borne and also probably cheaper, as the stone must be conveyed 30 miles from Dowlaishweram. I do not propose to make a bandy road along the aqueduct, because it leads only to the talook of Naggaram and is not on any great line of communication, and it is evident that all the heavy traffic will be by water."

Colonel Baird Smith, a distinguished officer of the Bengal Engineers, who saw the Aqueduct early in 1853, has the following description of, and remarks about, it in his 'Irrigation in the Madras Provinces,' and a plan of the work as it then was, taken from that book, will be found in the Atlas Volume of this 'History':—

"The passage of the branch is effected by means of the Gunnaram aqueduct, a work most creditable to the professional character of Lieutenant Haig of the Madras Engineers, the officer by whom it was constructed. It will be convenient to give a short description of it here. The total length of the aqueduct, between abutments, is 2,248 feet, divided into 49 arches of 40 feet waterway each at the springing of the arches, and 48 piers of 6 feet in thickness at the same points, with an external batter of 6 inches on each side. The abutments on both sides are segments of circles, having radii of 35 feet terminating in return walls, binding the work into the embankments of the channels, 15 feet in length each. These and the piers rest on wells 5½ feet in diameter, and sunk 8 feet deep in the sandy bed of the stream. Over the well-tops is a flooring which, in 25 arches, is composed of concrete, strengthened by five bond-walls of bricks, 2 feet in breadth. The flooring is 1 foot thick and is supported by five rows of wells, 4 feet in diameter, and sunk 3 feet in the sand beneath, the heads being secured by the bonds just alluded to, which run through the whole length of the flooring. The total height of the piers from the floor to the springing line of the arches is 11½ feet, the rise of the arches 7 feet, their thickness throughout 2½ feet; the height of the parapets above the line of the crown of the arches is 6 feet, and they are surmounted by light wooden railings 3½ feet in height. The top of each parapet is made to carry a foot pathway 6 feet in breadth for purposes of cross communication. The spandrels are not filled in; there is no flooring to the aqueduct channel between the parapets, which are 2 feet thick at top and 3 at bottom, with spandrel walls 1 foot thick and of lengths variable according to their position. The water thus flows over an exceedingly rough bed, and when I saw the work, there were several awkward rapids at different points of its length. There is a fall of 2 feet from the eastern to the western end, which is nearly at the rate of 5 feet per mile, causing great rapidity of current. The breadth of the channel varies a little, ranging from 22 to 24 feet. Loose-stone aprons protect the foundations in front and rear, and they will be extended as occasion requires. The architectural design is perfectly plain and hard; in fact the elevation is merely that of a wall with a series of holes through it, and its appearance is even heavier than there was any occasion for making it. The whole structure is of brick in excellent cement, the bricks being unusually large or 18 inches by 6 inches by 3 inches. To facilitate their being burnt in kiln, the length of each brick is traversed by a small circular hole half an inch in diameter. The results of this were so satisfactory that, on my arrival at Roorkee, I suggested its being tried in bricks of the same size required for the Ganges canal works, and the experiment has proved very successful, the material being burnt perfectly throughout its entire bulk. The little hole in the centre of the brick seems to act as a conduit-pipe for the heat and an escape for the moisture, so that the action of the fire generally is more complete. At first the moulding of the bricks required a longer time, but with experience this difference has almost disappeared, and the facility with which material so much above the average bulk can be now supplied fully compensates for the little difference that remains."

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. . . . "The average capacity of the channel of the aqueduct, with 4 feet of water, a slope of 5 feet per mile, and a mean breadth of 22 feet, may be estimated at very nearly 500 cubic feet per second; but on emergencies it is of course possible to force from 100 to 150 feet per second more through it without any very formidable risk. . . . .

"It is a point worthy of note, that the whole of this great work was completed in three months from the date of its commencement. Materials had been accumulated, immense working parties collected from the adjoining districts, and every preparation made beforehand. The water was then turned off into the Western Gódávary by the requisite embankments; and communicating his own energy to the whole establishment under his control, Lieutenant Haig virtually completed the aqueduct within the period I have mentioned. I must not conceal the fact, however, that this speed was paid for by a prodigious excess of expenditure on the original estimate amounting to close upon, if not quite to, 100 per cent. The officers on the spot maintained that there was real economy in this apparent extravagance, but the Government had very naturally been startled by its occurrence, and the matter was in active discussion during my visit to Madras; but how it has been settled I do not know, and it would require a much more intimate knowledge of the accounts than I have, to warrant any decided opinion whatever on such a matter.

"It is impossible to consider attentively the circumstances under which the Gunnaram aqueduct is placed, without having the question of its permanent stability forced upon one's consideration. It is unquestionably exposed to great risks. It seems to be possible to secure foundations on the rivers of Southern India, with their very low slopes, by means which, with our own experience of the rivers of Northern India, we would be justified in pronouncing utterly inadequate, and with which, in fact, we would never dream of operating, since they would inevitably fail on the first serious trial. I therefore conclude that, so far as the foundations are concerned, previous experience in other and similar localities is sufficient to warrant their being pronounced trustworthy. But the provision for the passage of the floods seemed to me inadequate. Within a few months (or possibly weeks, for I forget the precise date) after the aqueduct was finished, a flood rose, as I understood, not less than 5 or 6 feet over the level of the tops of the parapets, thus burying the whole structure under water. The height of this flood must have been about 30 feet, and it was no doubt an extraordinary one; but not so much so as to place it beyond the region of contingency, for which, in projecting such works, it is necessary to make some adequate provision. The sectional area of channel for such a flood, as provided by nature, is approximately about 72,000 square feet; that provided by the engineers is considerably overestimated at 30,000 square feet. It is only necessary to look at the elevation of the aqueduct, and to note the proportion between the solid and permeable surfaces presented thereby to the stream, to make it self-evident how serious an obstruction to the current the work must be in all considerable floods, but especially in those where the flood-level rises high on the parapets. I must confess my own conviction to be, that this aqueduct will be a constant source of anxiety, and that the probabilities are in favour of the repeated occurrence of formidable accidents to it. That this anticipation is not imaginary has been proved by the experience of the past season; and I quote a few words from a letter, under date the 19th August 1853, from an officer intimately connected with the works, showing that already the dangers to which the structure is exposed have exhibited themselves in a very serious form: 'The great aqueduct, by the way, has received considerable damage, the high and heavy side wall having broken and fallen flat upon three of the arches, which are thereby cracked considerably, and one of them very badly. This was caused by very high freshes which came down at an unprecedentedly early period.'" . . . .

The bed of the river at the site of the work is pure sand, and the floods at the place were, when the work was designed, known to rise to a level several feet above that which had to be adopted for the soffit of the arches.* With these conditions one cannot but be surprised at the boldness of a design which provided for founding the work on small wells sunk to only 8 feet below the bed of the river, and Colonel Baird Smith's anticipations of disaster seem natural enough. As a matter of fact, however, though parts of the Aqueduct have now and again received damage of no great extent compared with the size of the work, it has never been destroyed. After upwards of forty years it still stands, and with some improvements of its trough, to be hereafter noticed, it continues to perform all the duties that were expected of it, and more. Over it flows the irrigation water which makes the Naggaram island the 'Garden of the Gódávari' and along the navigable canal which it carries, passes by far the greater part of the traffic of that most prosperous part of the delta.

From the commencement of preparation of materials for the work till the completion of all its 49 arches, only four months elapsed, and in another four months it was ready to have water passed over it. In any part of the world this would have been a noteworthy achievement; in an out-of-the-way part of the Madras Presidency where machinery was almost unobtainable, and most of the skilled labour required had to be trained as the work went on, it was an extraordinary feat.

It will have been noticed from the extract above given from Baird Smith, that the cost of the work was greatly in excess of what was anticipated. The original sanctioned estimate was Rs. 73,200, whilst the revised estimate, which is approximately the cost of the work as at first constructed, was Rs. 1,68,935. No wonder then that the Government of the day was much exercised about the matter. Lieutenant (now General) F. T. Haig, R.E., who carried out the work, was called on for explanation of the excess, and he submitted a lengthy memorandum, from which, being full of interest on various points, the following copious extracts are made :—

"Sanction for the estimate arrived in December 1851; the first preparations for the work were commenced in the latter end of that month, brick-making in the middle of January, by the end of which month the river was banked out and the work commenced in its bed. During February very little progress was made in consequence of the failure of the brick kilns, in March we got on better, and by the 22nd May the last arch was turned. The flooring and apron were then commenced and had, on the 24th June, been completed as far as the 38th arch when the river rose, carried away the bunds and passed through the work. Providentially no accident occurred. The cross wells had been sunk in the bed under the last 11 arches and some loose stone thrown round the piers, and this protected them from any injurious action of the water. A subsequent fall of a few feet in the river enabled us to cover over all this part of the flooring with a layer of loose stone packed, and it has sustained no injury whatever from the last high flood in August.

"The side wall had also by the middle of June been built to a height of 2 feet about one-third of the length of the bridge, and the backing of about three-fourths of the arches was completed.

"They are now almost finished, and there seems every probability of the work being ready for the water in a fortnight.

"The work consists of 49 arches of 40 feet span each, resting on piers of stone and brick with well foundations and a flooring of concrete under the arches with a small apron of loose stone beyond it.

It differs from the original plan in one or two particulars.

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* Floods have really gone clean over the whole work, *see* further on.

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"*First, in length.*—The estimate allowed for only 39 arches to span a width 600 yards and provide a very massive flooring and apron of loose stone to protect the bed under the arches from the effects of the rapid current caused by the great obstruction which the work would offer to the passage of the water in high floods, but it was afterwards determined to place the aqueduct at a point lower down where the width of the river considerably exceeds the average when consequently the obstruction would be less, and there would be less danger of an accident from the velocity of the current undermining any of the piers, and it was supposed that this velocity would be so much less than what it would have been on the former case that a much lighter apron than the estimate allowed for would be sufficient and that the saving thus gained would meet the additional expense involved by the increased length of the work.

"The flooring thus substituted for the one originally intended consists of five rows of wells, one immediately in front and another 6½ yards in rear of the work with three intermediate ones under the arches on top of each row, a wall 1 foot high and 2 feet wide was built at the level of low water and the spaces between these cross walls filled in, first with 6 inches of broken bricks and tough clay well rammed and then with 6 inches of brick and chunam concrete.

"The surface of this floor was then levelled and plastered with a hard and quick-setting cement. In front of the up-stream cut-water of the piers, the front row of wells was extended in a ring with a radius of 4½ yards.

"Along the front of the upper row a small apron of brick rubbish was thrown and along the rear of the lower line a similar one of rough stone.

"*Second.*—The arches also as built differ from the original plan which were proposed to support the water passing over the aqueduct by one main arch 19 feet wide with a rise of 7 feet and the towing path by another 9 feet wide with a rise of 13 feet, both springing from the same line on the piers. For these two, one arch, the whole width of the bridge has been substituted, with the intention of supporting the towing path by joists resting at one end on the side wall, and on the other on a small arch 2 feet wide, turned over the main arch, but springing from a higher level and with a greater rise, thus securing nearly the whole width of the towing path of waterway more than the originally proposed construction admitted of.

"These are the only alterations introduced in the construction of the work.

"The estimate was Rs. 73,200-6-4, the expenditure up to the 31st August has been Rs. 1,31,769-2-4, excess Rs. 58,568-12-0.

"The subjoined is an abstract of the estimate and expenditure up to the 24th July, the expenditure since then having been placed in the bill without any details (which there has not been time to furnish) and being mostly chargeable to the contingent expenses :—

—	Estimate.	Bill.	Excess.
	RS.	RS.	RS.
Masonry	29,748	48,506	18,758
Wells and apron	28,720	36,884	8,164
Plastering	3,732	...	...
Contingent expenses	11,000	36,313	25,313
Total ...	73,200	1,21,703	52,235

"It is evident from it that the excess is mainly owing

(1) to the masonry costing half (½) as much more than the estimated rate.

(2) to the contingent expenses, the embankments, baling, centrings and contingencies, amounting to three times what they were estimated at.

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"So large an excess is difficult to account for, that in the cost of masonry especially.

"The estimate allowed Rs. 2 per cubic yard for the plain masonry and Rs. 2½ for the arch work, and from the experience gained on the work, I am confident this was ample and would not with good management have been exceeded if there had been sufficient European superintendence and the estimate had been sanctioned in time to allow of our making preparations such as collecting wood, making bricks, &c., beforehand.

"The bricks for the anicut were made for Rs. 1½ per 1,000 and sometimes for less; this is the average price also throughout the Delta, though certainly for bricks much inferior to those we used in the aqueduct, and there was every reason to suppose that with European superintendence, and using wood which was then being cut in the hills for much less than formerly, this would be the outside our bricks would cost.

"The cost of the chunam has hitherto been reckoned at Rs. 5 per garce * at the kilns, preparing it for use by mixing with sand, grinding, &c., ought not to be more than As. 4 per cubic yard, altogether As. 8 per cubic yard. If we substitute these prices for the actual ones in the cost of the plain and arch masonry, it will be found that it brings it down below the estimated rate.

"The extremely high price of these two materials, bricks and chunam, but especially of the former, is the main cause of the excess in the cost of the masonry.

"The actual cost of the bricks per 1,000 was—

	RS.	A.	P.	
1. For moulding	0	7	8	
2. Stacking and burning	0	9	4	
3. Carriage of the wood to kiln	0	7	8	
4. Wood	1	11	5½	
5. Sand for mixing with the earth of which bricks were made	0	1	9½	
Sundries	0	5	0	
Total ...	3	10	11	per 1,000.

"Every item in this bill, with the exception of the first, is high, the second, third and fourth excessively so, and making every allowance for the hurried way in which the bricks had to be made and my own inexperience, it seems impossible not to suppose that some of the excess at least is attributable to mismanagement, though to the zeal, energy and untiring industry of the two Europeans who were successively in charge of the brick ground, I bear most willing testimony. I have no doubt that if I could have paid more attention to the brick-making and more narrowly watched the process of burning, not only the great improvements in it which were latterly introduced would have suggested themselves at an earlier period, but the expense of manufacture might in other ways have been very materially lessened. It must however be remembered that the whole of the bricks, 108½ lacs, were burnt in about three-and-a-half months, or at the rate of 1 lac per day nearly, so that I had not much time for trying experiments, and what I had was but too constantly occupied with the superintending of the other parts of the work. In fact every particular part of the work suffered from the want of more European superintendence, though I had all and more than could well be spared from the other works in progress in the Delta. My time was so completely occupied with superintending all the petty details of the work which might have been equally well looked after by subordinate Europeans that I could never bestow that attention upon any one part of it which it required. A larger and better trained European superintendence would have effected an immense saving.

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* Garce = about 108 bushels.—G.T.W.

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"In a work carried on in this country at the rate at which this was, one European to every 400 coolies would be only sufficient, whereas the most I ever had was one to 1,000, and that only for a short time, and for the greater part of the time, one to 2,000, and this with scarcely one single native with the exception of a native maramut superintendent, of whom I shall speak afterwards, and one or two others, who was worth anything.

"The coolies are grossly idle, the bricklayers worse and the peons worse still. It is not too much to say that there was scarcely a native employed on the work who, if unwatched, would not have sat still half the day and done nothing; practically, what with the idleness of the coolies and the ignorant and useless way in which they waste so much of their labour and the utter inability of the native peons and maistries to direct them, I do not believe that the amount of work got out of each man was more than half what it might have been.

"The difficulty of burning the bricks thoroughly, met us at the outset; the first kilns were burnt in the English manner under Overseer Sage, and precisely similar to those in which he had a few months before burnt without any difficulty all the bricks required for the Chettipet lock and calingulah, but every kiln when opened turned out a complete failure; the bricks were only half burnt and the utmost care and most vigilant watching of the fires both day and night by Overseer Sage produced no better result; the native clamps were then tried such as are generally used throughout the district; the men who had burnt all the bricks for the anicut and for Messrs. Arbuthnot's factories tried every sort of clamp but without success, though a reward of Rs. 50 was offered to any man who would turn out a well-burnt one;—all failed.

"We then resorted again to the English kilns and after many experiments succeeded by modifying the construction so as to secure a greater draught and stronger heat in burning the bricks properly. An immense quantity of wood was used on these experiments and a large number of bricks wasted, the cost of which has of course all been added on to that of the bricks afterwards made.

"Having once found a way of burning the bricks, we were only too glad to adhere to it, though we afterwards found towards the conclusion of the work that it was capable of very great improvement, the form and dimensions of kilns we had used was the same as that in general use at home, and which the overseers and sappers are instructed how to use at head-quarters sappers and miners; but we found that it was narrowed more than was necessary and gradually went on widening it till we found at last that kilns of double the width, and holding consequently double the number of bricks, were thoroughly burnt with just the same quantity of wood as was used in the kilns of ordinary shape. Had we known this at starting, a saving of one-half the quantity of wood used would have been effected.

* * * *

"All these causes helped to raise the price of the bricks, but the principal ones were our inexperience in brick-burning and the waste of labour through the want of sufficient European superintendence. The cost of the chunam was as follows:—

	RS.	A.	P.
At kiln per garce	7	6	3
Carriage from Rajahmundry and Dowlaishweram ...	1	14	5
Carriage from boats to mills, mixing and grinding in mills, and sand	7	10	10
Materials, superintendence, sundries, cost of mills, &c., &c.	0	15	9
Per garce ...	17	15	3

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MINISTRY OF CULTURE · GOVERNMENT OF INDIA
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"The cost of grinding and carriage to the mills is also very high, but 288 garces for the arch work out of the whole 782 were beaten by hand after having been ground, to secure better admixture which would at once double the cost of this portion, and the sand for all the work had to be brought from a distance of 400 yards and then sifted.

"The chunam was also nearly all carried by coolies for expedition sake from the boats to the mills an average distance of 400 yards, and at the commencement of the work very much farther. I do not, however, put these forward as sufficient reasons for the high price of this item in the cost of the mortar, which I think is mainly attributable to the waste of labour from want of better superintendence.

* * * *

"The centrings cost more than double what the estimate allowed. I do not think they could have been put up and removed with the same speed for less money; 30 out of the 49 arches were turned at the rate of from 1¼ to 1½ arch per day; we had consequently to put up the centrings at this rate, 22 were in use being struck and moved to the front for the next arches. They were made of palmyra trees which had to be cut and carried to the shot by boats and bandies, and had to be moved about at the work entirely by hand.

"The baling and embankments were estimated at Rs. 3,000; they cost Rs. 13,802, the embankments alone costing Rs. 5,304 and the baling Rs. 8,497.

"It was hoped that the whole of the baling would have been done by steam for a trifle. The engine, however, which drove the baling wheel, was not ready in time for the first part of the work, and the foundations for the piers were baled entirely by coolies.

"It was, however, up and ready for work in time to have drained the bed of the river to the depth required for laying the flooring and apron, but owing to insufficiency of steam and one or two other minor difficulties, it turned out to be of little or no use after having been put up at an expense of Rs. 4,358, and the whole of its work had to be done by coolies working both day and night and at a great expense.

"Heavy rain setting in too before the flooring was completed greatly increased the cost of baling drawing the night coolies away from their work, while the basin filled mean time both from the rain and springs in the sand, and all their works had to be done over again.

"It was necessary to keep from 500 to 700 coolies at work baling all day and the same number at night, and the pay of the latter had of course to be increased to As. 2 per man.

"The embankments cost more than with better management they need have done. In attempting to shut out the tide water at the commencement of the work, we spent Rs. 1,500 on a bank which we were eventually obliged to give up to make one in place of it at a more favourable point in the bed of the river; five distinct banks were required, whose aggregate length was not less than 2,800 yards, to shut off the river and tide water. One across the river immediately in front of the Aqueduct and another in rear with a sluice to keep the water in the inclosed basin down to the level of low water, and three others higher up the river across the heads of the Vynatheam branch by which the freshes were kept out until the 24th June. All had to be made very strong and faced with tatties to protect them from the waves during squalls, and the two at the work required a party permanently stationed on them to watch and repair them.

* * * *

"I have thus stated the particular reasons which I think may be assigned for the excess in each portion of the work. The three main causes undoubtedly were, the want of time for preparing and collecting materials beforehand, our

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inexperience in brick-burning, and the great waste of cooly labour from the insufficiency of European superintendence."

* * * *

Colonel A. Cotton's contribution to the discussion was the following report of 23rd December 1852 :—

REPORT ON THE EXPENDITURE UPON THE NAGGARUM AQUEDUCT.

"The great excess of cost in this work is no doubt mainly owing to the haste with which it was constructed. Receiving the sanction after the working season had commenced, there was of course no other choice than either to give up the attempt to get it finished in one year, or to push it on with the utmost effort, whatever difficulty occurred : as I have before endeavoured to show, the results of these works are so great, that there can be no sort of doubt that the policy is to save time at almost any cost. The progress of the district, even as shown by the increase of revenue only, since the works were begun, seems to me to show the certainty that almost any increase of cost is warranted by bringing the works into operation a year earlier. Being myself quite satisfied on this point, I determined to try if possible to get the work out of reach of injury before the monsoon. In doing this we could not let any means slip on account of their cost ; and when we met with difficulties, such as those in the burning the bricks, as mentioned in Lieutenant Haig's report, we could not stop to make experimental kilns of a few thousand bricks : we were obliged to continue making and burning them by lacs without loosing a day. As is so commonly the case, this difficulty was one we least expected, having a most intelligent and able overseer, who had been just before burning bricks with the most perfect success at other works. But both he and the native brick burners were entirely at fault. I have no doubt that the principal cause of our failures was the peculiar nature of the soil, which was that in which the tobacco is grown, and had never been used before for bricks. It evidently requires a much higher heat than ordinary brick earth. I mention this as a specimen of the obstacles we met with in pressing on the work. There were many other things which delayed the work, and compelled us to adopt every expedient we could think of. But when we were fairly committed in the work, there was no question but that we must go through with it ; for had we not got all the arches turned, and the flooring and apron laid before the freshes, the whole work might have been destroyed.

"2. Upon looking over the accounts and reports I am satisfied that the extra cost is chiefly but not entirely accounted for by the rapidity with which the work was carried on. That a single officer, with two or three overseers, should have managed about 5,000 workmen in all, including boatmen, wood-cutters, &c., and with the help of only three or four efficient workmen, is one of the most surprising things I have met with. Every time I visited the work I was astonished at the energy and admirable arrangement of this young officer. I cannot say less than that I think him the most effective officer I have ever had attached to me. It must be remembered too, that this was the sixth year in succession that he had been employed in these works, during all which time he had gone through much more fatigue and exposure than any other man in them ; in consequence of which he was considerably shaken, and at times compelled to lay by for a day or two. I have never yet seen such energy displayed by any other man.

"3. I must allow that in thus carrying on the work considerable risk was run ; but nothing of any consequence was ever accomplished without running risks. It was very remarkable that, while the men were actually at work upon the aqueduct, a flood should have occurred within a few inches of the height of that of 1849, which was more than a foot above any previously known ; and *that* in the end of July, and not at the time when the high freshes before invariably occurred, namely, in September. The nature of the work required that the tops of the arches should be five feet below the surface of the river in the freshes ; so

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that it was a very different case from an ordinary bridge or aqueduct. That a work of this kind, while the masonry was quite soft, should have stood such a trial, was certainly little short of a miracle; and we have reason to be thankful that it stood it.

"4. I trust we have thus saved a year by God's blessing on our labours. The advantage of this gain should not be measured by the first year's return, nor even by a year's return when the talook has been got into good order, but by the total of the differences of a series of years. There are 50,000 acres of valuable land in the talook; and when fully cultivated, a large portion of it with sugar, chillies, plantains, &c., a year's produce will be worth ten lakhs, even if only a quarter of it is under such culture.

"5. I should state, however, that though I am of opinion that the estimate was a liberal one, as compared with the actual cost of other smaller works (for I made considerable allowance for the loss occasioned in various ways in a work of so great extent), yet I do not think the estimate was sufficient; that is, I think that even if two years had been allowed for its execution, there would still have been excess of expenditure. The sources of loss in a work of this length are much greater than would be at first expected. We had indeed experienced this in the case of the Annicut; but then there were still greater ones in commencing that work than there were in the present case.

"6. The principal cause of the excess, however, undoubtedly is the hastening of the work with such a small amount of superintendence, and when the channels, by which the whole of our materials must be brought, were in quite an imperfect state; so that besides many interruptions, the boats were never fully loaded, or even nearly so. I may here mention by the way that, notwithstanding this, we had a remarkable proof of the value of water carriage; for, though we had no less than 200 boats hired besides our own, so that they could not be properly looked after, the cost of transit by calculation of the actual money expended compared with the weight carried, comes to only three pice a ton per mile, and that with comparatively short trips,—about one-eighth of ordinary land carriage in the dry season. From this I should conclude, that for long distances, with channels four feet deep, goods would be carried for half or one pice a mile, and down a river where the traffic was in the direction of the stream, certainly at half pice, a price at which perhaps twenty times as great a quantity of traffic as at present would be carried on.

"7. If it is asked whether after this increase of cost and risk has been incurred, I would still approve of the work having been carried on these principles, I answer I would assuredly recommend that such a plan should be adopted in similar circumstances. In the present state of things in India, in the almost entire want of these works upon which its prosperity depends, I am convinced that the true policy is to press on with the utmost effort and at all risks. The poverty of India is not caused by the failure of works, or waste of money in executing them rapidly, but in failing to execute them at all, or in doing that in two years which might be done in one. Till we have food and transit with less labour, the country will continue to be paralyzed. While almost everything we do yields from 50 to 100 per cent. in revenue, and probably 200 per cent. in total results, there can be no question about the real state of the case. Upon the best information I could get in Tanjore, there seems no room for doubt that the lands, which were on an average saleable at Rs. 160 a vaylie before the Annicuts were built, are now worth 300; so that on the 100,000 vaylies of irrigated land there would be an increased value of 140 lakhs, or twenty times what has been expended in improvements, besides the gain in revenue. And I have not the least doubt that both communications and irrigation will everywhere produce property to the value of much more than twenty times the outlay. The fact is, that India in its present unimproved state is a mine of wealth, far beyond that of any gold mine in the world. The richest mines in Australia only produce about three-and-a-half times the value of the labour bestowed on them; a man whose labour was worth £35 a year, earning on an average £120 a year in mining.

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“8. It is by such tests as these that we arrive at a correct idea of the value of our public works in India, and at a true judgment of what sacrifices we are justified in making in carrying them out, and what is the value of time in the case. It is this view of the matter that has influenced all my operations, and I am convinced that it is a correct view, and will stand the test of the closest examination.”

“NOTE ON PARA. 4.

“The effect of the delay of a year in the execution of the aqueduct may be thus shown.

“The increase of revenue in the district generally has been 20 per cent. annually since the works began. The increase in any particular portion of the Delta from the time the water began to be distributed over it ought therefore to be much greater. Taking however 20 per cent. upon the present revenue (I believe about Rs. 1,50,000) the account would stand thus :—

Collections.

	Increase commencing one year earlier. RS.	Increase commencing one year later. RS.
First year	1,80,000	1,50,000
Second year	2,10,000	1,80,000
Third year	2,40,000	2,10,000
Fourth year	2,70,000	2,40,000
Fifth year	3,00,000	2,70,000
Total ...	12,00,000	10,50,000
Deduct ...	10,50,000	
Gain ...	1,50,000	

“That is to say in five years one and-a-half lakh of rupees would be gained by executing the works a year earlier.”

* * * *

In August 1853 an unusually high flood damaged the Aqueduct; the nature of the damage is thus described by Major F. C. Cotton in his letter of 29th August 1853:—

“18th. The Gunnaram Aqueduct has, I regret to say, met with serious injury by the splitting of one of its piers, and I think the sinking of one if not two of those near it.

“19th. I send a sketch of the position injured. It is impossible to say, till the flooring is in sight, what has actually occurred, but from the sinking of the foundation when the aqueduct was submerged, it is evident that the building did not sink from its weight only, and the probability is that the current with a head of 1 foot 9 inches washed out the sand from below the packed stone flooring, which sinking left the wells exposed.

“20th. The flooring of these arches could not (as before reported) from want of time be laid down this season, but Mr. Fuller packed the stone with care and would have loaded it with a covering of heavy stones if the fresh had not come upon him so unusually early.

“21st. When the pier failed, the arch on either side cracked in curves round the centre that had sunk, and the parapet walls must have split at the same time so as to be easily overthrown by the current.

“22nd. Under the impression that the injury done to the arches was caused by the wall falling, the spandrels have all been filled up with earth, except that of the

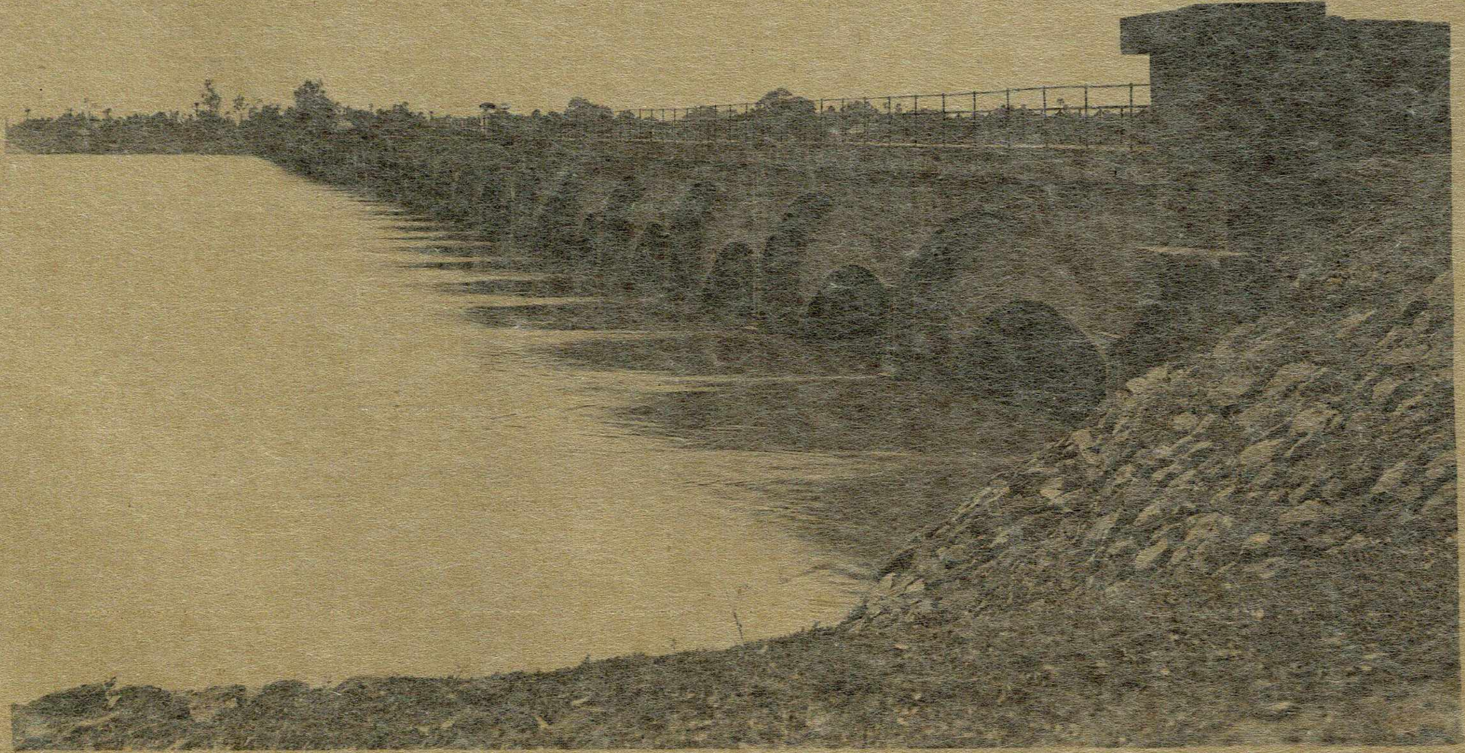

Photo.-Print Survey Office, Madras 1896.

GUNNARAM AQUEDUCT.——DOWN STREAM FACE,

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sunken pier which has been raised with brick in chunam in the hope that, when the water sets, it will bind the shaken parts together.

"23rd. Filling up the spandrels to nearly the level of the arches, will prevent any ill-effect from the walls should any other accident of the kind happen, but will add to the weight on the foundation, and the plan proposed by Colonel Cotton of building cross walls over the spandrels will be the best mode of preventing such accidents hereafter.

"24th. The pier, eastward of that which was most injured, has its wells so much exposed that Mr. Fuller pushed a bamboo amongst them and the cause must have been the same as that above shown. The sand below the flooring was washed out, the stone sunk, and left the wells unprotected.

"25th. These piers will now be secured as well as time will permit, and I have desired Mr. Fuller, in case stone is not supplied fast enough, to take off the upper part of the parapet walls where they are of stone and use the material in largest cubes to load the flooring near the piers, giving all the support he can to the nearest uninjured piers to enable them to act as abutments should the injured arches fall.

"26th. I need not now give my plan for the repair of this work, as we have first to see what effect the September fresh may have upon it; but in whatever state it may be left, I shall, I hope, be able to so arrange its temporary and permanent repairs that the sugar crop of Naggaram may not be injured."

This accident threw the Aqueduct out of use for some time, but in the following February we find Major F. C. Cotton writing: "We have had to carry the water over the damaged arches by earthen banks" . . . . and "There is now 2 feet of water passing over the Aqueduct, and a crop of great value is dependant on the work."

The repairs of this injury cost Rs. 15,142, and a further estimate of Rs. 15,450 was then sanctioned for "strengthening the whole of the flooring with a covering of large rough stones and for laying narrow rough aprons above and below the Aqueduct for the regulation of the river bed."

The floods of 1854 again caused damage to the work, thus described in a letter of 5th October from the 'Secretary, Public Works Department, to the Chief Secretary to Government':—

"The accident is believed to have been caused by the sinking of the rear apron of loose stone and the consequent exposure of the wells under the retaining wall of the flooring, which being thus undermined gave way and brought down two piers and three arches.

"It is possible however that the flooring may, from its imperfect strength at that part of the work, have been directly acted upon and broken up by the current, but this is not considered probable.

"Notwithstanding this second disaster, Lieutenant Haig is of opinion that the work may, by means of additional material, the necessity of which has been taught by experience, be entirely secured against future accidents."

The repairs of this damage appear to have cost only Rs. 6,672, but in 1855 an estimate of Rs. 36,112 was sanctioned for "completing and strengthening the floors and aprons."

At the end of 1855, Rs. 23,360 were sanctioned for "building a towing path on each side of the Naggaram Aqueduct" carried on light arches sprung from the ends of the piers.

After this, no special estimate connected with the Aqueduct can be traced till that included in the 'Completion estimates,' which will be noticed in the next chapter; and no further accident appears to have happened to the work till 10th August 1884 when "the right-hand* trough-wall with the tow-path over the last three arches at the lower end of the Gunnaram Aqueduct (a length of 160 feet) gave way and fell into the river." . . . "The principal if not the only cause of the failure of the work was the insufficient section of the trough-walls of the Aqueduct to withstand the extra pressure which they are now required to resist, by the altered hydraulic conditions" due to the works carried out, under the 'Completion Estimates,' in order to improve the navigation by lessening the velocity of the water through the Aqueduct; the surface fall through the duct had been reduced from about 3 feet, to 8 inches, and the water surface raised at the lower end of the work by nearly 3¾ feet. The irrigation requirements of the 32,785 acres served by the Aqueduct were provided for by a wooden trough carried over the damaged part of the work till the end of the irrigation season, after which the fallen wall was replaced by a stronger one and the whole of the side walls of the duct were strengthened sufficiently to enable them to bear the pressure against them.

The two prints opposite pages 72 and 83, from photographs by Mr. W. J. Howley, Esq., Assistant Engineer, show the Aqueduct as it now is.

In the great flood of October 1891, the Aqueduct was entirely submerged, but received only, very slight damage, particulars about which are given in the following extract from Inspection Notes of the Chief Engineer for Irrigation, printed with P.M.G., No. 34, I., dated 14th January 1892:—

> "The flood of October went right over this fine old work about 18 inches deep in the middle, and from that to 6 inches deep near the ends; the greatest difference of level in the river above and below the work was 2·4 feet. The only damage to the superstructure was the washing off of some of the surface gravel and a little picking up of the concrete of the right tow-path, and some slight injury to the railings. The rough stone flooring in river bed below the work has on the left side of the river been somewhat disturbed and must be repacked; in doing this it will be well to keep the surface down as low as possible taking care of course to make the junctions of the surface of the new and old packing with gradual slopes and not sharp edges. Where the deepest disturbance is, opposite the first bay, it will probably be advisable to put a row or two of piles in the way often done in dealing with troublesome places in the anicut aprons. A reserve of stone should be invariably kept near each end of this work. The flooring put down in the last three years along the front of this aqueduct has added much to its safety."

The flooring referred to at the end of this extract was commenced in 1888–89, under the instructions of Colonel H. R., Mead, R.E., then Chief Engineer for Irrigation, and finished in 1890–91 at a cost of Rs. 39,000. It is formed of concrete, 1 foot 6 inches thick and 15 feet 6 inches wide; along the front edge of this runs a rubble retaining wall 2 feet 6 inches wide × 3 feet deep, resting on square wells 5 feet in depth. This was put down along the whole breadth of the river except opposite the three western arches of the Aqueduct, where the débris of the wall which fell in August 1884, as above described, had already formed a very effective apron.

The print on the opposite page, from a photograph by Mr. Howley, shows the appearance of the Aqueduct when the great flood above referred to was going over it.

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* From Report by the late Colonel P. Montgomerie, R.E., with P.M.G., No. 911, I., dated 10th October 1884.

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CHAPTER VII.

WORKS IN THE DELTA—SANCTIONS, EXECUTION, COST.

Before Colonel A. Cotton left the district (*see* end of Chapter IV), he had obtained sanction for and partly carried out the works included in the following estimates:—

1. 'Cutting Dowlaishweram Channel' (now known as the 'Main Canal, Eastern Delta'), Rs. 53,107; sanctioned 14th December 1849.

2. 'Cutting Rallee Channel' (now known as the 'Main Canal, Central Delta'), Rs. 34,014; sanctioned 14th December 1849.

3. 'Enlarging the Channel at the head of the Western Delta' (now known as the 'Main Canal' of that Section), the excavation of the Kakaraparru Canal, the construction of a Lock at Narsapur, the improvement of the 'Gostanadi' (a natural Channel, *see* Chapter I) and of the 'Venkiah' (a Native Channel from the Weyéru, *see* Chapter I)—Rs. 76,397; sanctioned in April 1851.

4. 'Improving the Tuliabaga' (now part of the Cocanada Canal), Rs. 9,938; sanctioned in May 1851.

Note.—Two * Locks had already been built on the Tuliabaga 'to make it navigable', in 1848.

5. 'Works in the Central Delta,' Rs. 1,38,647; submitted in August 1851, sanctioned 14th February 1852.

The chief items of this estimate were—

'Widening the Main duct from 10 to 15 yards.'

'Enlarging and straightening' the Gorinkala, and building in it two Locks and Weirs to make it navigable to the Vainatéyam Gódávari near Gunnaram.

Constructing a branch to irrigate 22,000 acres called the 'Pallavella Channel' (now the Amalápuram Canal).

Another branch called the Naggaram Channel (now the Gunnaram Canal:)

Building a 'large Aqueduct for the passage of the same Channel over the Vainatéyam Gódávari.' (This is the 'Gunnaram Aqueduct' to which Chapter VI is devoted.)

'Prolongation of the Naggaram Channel and its division into Channels running along the banks of the Vasista and Vainatéyam Gódávari respectively.'

6. 'Works on the left bank of the Gódávari' (*i.e.*, in the 'Eastern Delta'), Rs. 1,76,357; submitted in 1851, sanctioned 14th February 1852.

This estimate appears to have been reduced from one sent in some time before for Rs. 2,83,630, of which it is said † "the leading idea" . . . . "was the provision of irrigation for 240,000 acres" . . . . . "and the completion of navigation of the Main, now termed the Bank, Canal to th tide waters of the Eastern Gódávari." The reduced estimate provided for "the excavation of the Bank Canal towards Yanam in French territory; the Coringa Canal to meet tide water at that place; the Injeram Canal with its head on the Coringa Canal and running towards Yanam; and the Mundapetta Canal taking off from the end of the Main Canal and joining the Coringa Canal. Various other subsidiary works, such as locks and calingulahs where required, branch and minor irrigation channels and improvements to the Cocanada and Samalkot Canals, were also included in this estimate, but the individual items are not known."

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* *See* letter No. 299, dated 20th May 1855, from the Chief Engineer to the Secretary to Government.

† 'Narrative of the Gódávari System,' paragraph 21.

The Canals and Channels of these estimates provided for distribution of water to some parts of the delta, but were quite inadequate to make full use of all that the construction of the Anicut rendered available. Colonel Cotton of course foresaw that much more than was included in these estimates would be necessary, but probably he considered that before the financial success of what had been done became apparent, it would be impolitic to raise alarm by giving an indication of the large sum that would have to be spent to fully carry out his great scheme. His staff also was small and overworked, and it was therefore not possible for him to submit anything like a comprehensive project in detail for the whole delta. He therefore sent in from time to time merely such estimates as were more immediately required. Even so, we found difficulty in getting the sanctions he asked for. Towards the end of the time when he was in Engineering charge of the Gódávari District, and whilst he was Chief Engineer, the records teem with remonstrances from him, and with 'minutes,' 'notes' and letters by Governors, Members of Council, Boards and Secretaries, now wrathful, and now penned more in sorrow than in anger, on the subject of the surprizes which Colonel Cotton was springing on them in his demands for, what they considered, unexpected developments of the original scheme, or to cover expenditure incurred on work which had not been sanctioned, or had been much altered, or largely exceeded, whilst in execution. For instance, in November 1852 Colonel Cotton, then Chief Engineer of the Presidency, addressed the following letter to Government direct instead of through the usual channel, the Board of Revenue. The letter is given *in extenso* as being interesting, as well as highly characteristic :—

"1. Five weeks having now passed without any notice having been taken of the estimates for further works in the Western part of the Delta of the Godavery, and fearing therefore that we shall be again subjected to the evils which have twice before happened during the prosecution of this project, viz., the delay of the sanction of the works till the working season was already well advanced, leading to the greatest confusion and unnecessary expense as well as to needless delay in the execution of the works, I have the honor to submit the following remarks on the subject and earnestly to request if possible immediate attention to them.

"2. The whole project having been already sanctioned by the superior authority, and now the most perfect success having attended the execution of the works, and far more advantage having been obtained from them than could possibly have been hoped as shown by the statements that have been forwarded as well as by those now appended, I have fully hoped that all opposition to this great undertaking was now at length at an end and that the money required for the prosecution of the works would be sanctioned without any delay as fast as it could be expended, and I have not considered it necessary to do anything further than simply report progress and results and forward the estimates, as we were prepared to carry on the execution of the works.

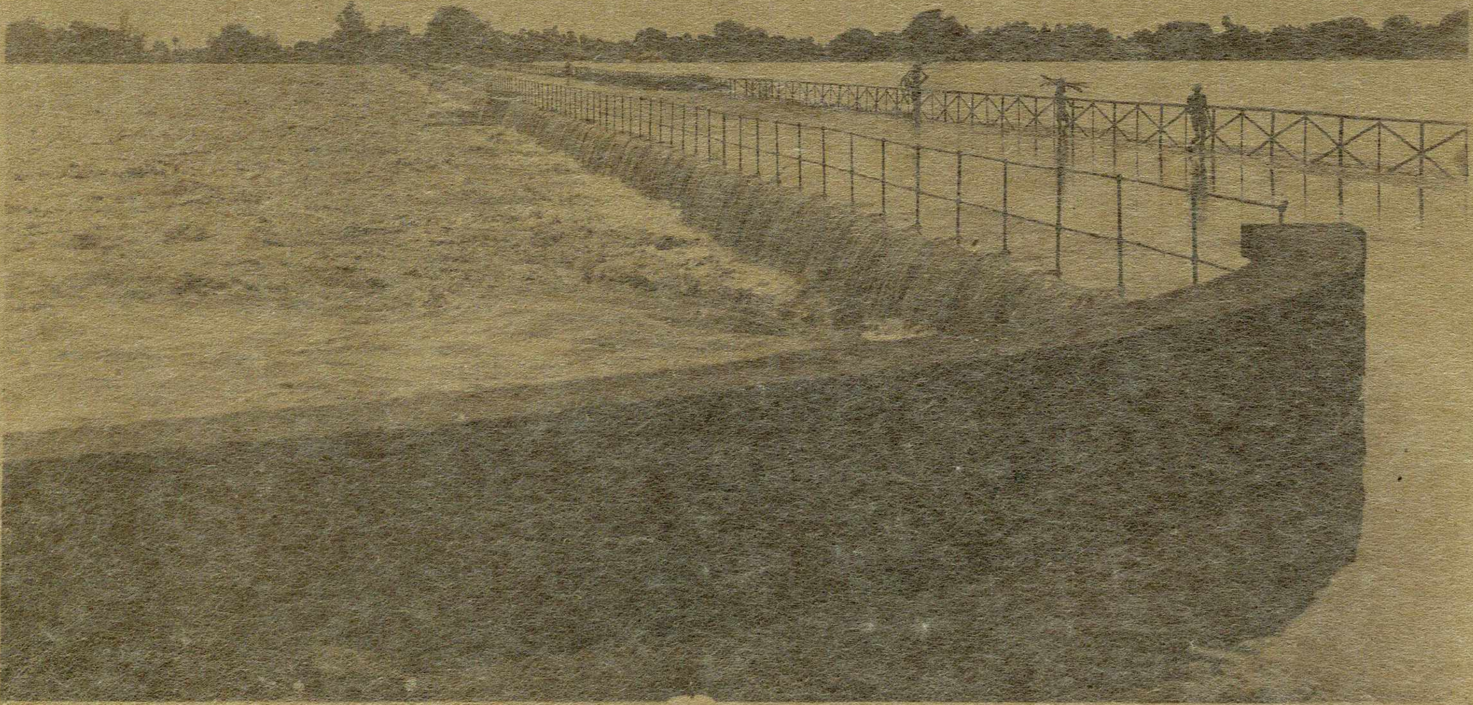

Photo.-Print Survey Office, Madras. 1896

GUNNÁRAM AQUEDUCT,

VIEW FROM UPPER END, WHEN SUBMERGED BY FLOOD IN OCTOBER 1891.

"3. The history of this project so far as the execution of the works is concerned is as follows. The project was sanctioned by the Hon'ble Court early in 1847. The sum then applied for was 4¾ lacs estimated in detail for the anicut with a rough estimate of 12 lacs for the remainder of the works. The works were accordingly commenced before the middle of that year and prosecuted vigorously during the whole of 1848. By the end of the working season the failure of the anicut estimate was ascertained and a further estimate of 4$\frac{1}{14}$ lacs was therefore forwarded. I need only remark here that this failure was entirely owing to the vast extent of the works so much beyond anything that have ever been undertaken before carrying works across the bed of a river 4 miles broad and the extra expense arising from which have been quite miscalculated, and to the inadequacy of our means especially in respect of Railway waggons to provide the material in sufficient quantities. Though the works were thus left in a most critical state, exposed unfinished as they were to the freshes, only a small sum was sanctioned for the important purpose of keeping the establishments together and doing anything that might be necessary to secure the work, and when this sum was exhausted further sums were withheld, so that no large body of workmen could be kept together or sufficient materials prepared for the following season. The officer was kept in a state of complete uncertainty, and it was not till the month of February when the cold season was over and the freshes were again approaching that sufficient means were placed at his disposal for the works. Half of a season was thus lost and the works needlessly exposed again to the freshes in an unfinished state, while all that was done was of necessity executed under the greatest possible pressure of haste, in order to put it even in a tolerable state before the river filled. By the greatest exertions through the excessive heats of May and June (the thermometer generally above 100 in the shade) Captain Orr succeeded in placing the work in such a state that no serious mischief was done. In the following season the anicut was placed in a state approaching to completion, but from the officer in charge of the division being obliged himself to superintend the actual work on account of there being none but young officers besides, his time was wholly occupied in that manner and scarcely any progress was made in cutting the Heads of the channels and none at all on planning and estimating the minor works. From the severe trial to which the Western branch of the work was exposed in that year, the overfall over it being much greater than had been anticipated, it was deemed safe to lengthen it, and an estimate was prepared and submitted again many months passed before the money was ordered for this work and when it came, it was quite too late to [illegible] work, so that that branch was again exposed to the same trial as before. [illegible] had [illegible] not in expectation of such dealing with the work done everything I could think of, to secure the work independent of its being lengthened, the probability is that there would have been an accident which would have cost as much money and lost us a great part of the season again.

"4. In the meantime the only two experienced officers, besides the Senior Assistant, were removed, and several of the European Non-commissioned Officers, and they were not replaced, by which the work was seriously hindered.

"5. Of the further estimates that were submitted in 1851, after many weeks one was returned refused, leaving us in expectation that the other would also, and thus entirely preventing us from making any satisfactory arrangements. At length, however, when the working season was well advanced, the further estimates were sanctioned, but in the meantime the season for making our preparations was lost, and we had to choose between losing the year or again pressing everything on with the utmost haste to get our works in a state to sustain the monsoon. As anything was better than delay, the latter alteration was adopted though it must be acknowledged at great risk. The great aqueduct especially, of 49 arches, had to be carried on without any materials collected beforehand, the hutting for 5,000 people to be erected and every sort of preparation to be made. By the wonderful energy and talents of Lieutenant Haig, who alone

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superintended this mass of workmen without any other officer, and though at a great and otherwise unnecessary expense, the work was in five months in a state to allow of the freshes passing under it, and in the following month it had to stand the trial of an almost unprecedented flood.

"6. Thus, notwithstanding these most unnecessary delays and consequent difficulties, the works have been executed with the most complete success and the results have been beyond all expectations. Already the revenue has increased 6½ lacs and the exports 6½ lacs; of course the question will be asked, but is this owing to the anicut? The average collections of the previous six years were 19½ lacs; it has increased since begun on an average a lac a year, being now 26 lacs; such an increase was never seen in any district before, and if it was not owing to the anicut, it is certainly the most wonderful coincidence; I have no doubt that almost the whole of this is either directly or indirectly owing to these works. A great part of it is directly produced by them, viz., by land being watered, drained and protected from river floods; one village (Biccavole), for instance, which yielded up to the year it received water, on an average Rs. 2,900 a year, immediately improved till it now yields nearly 10,000 rupees. It must be observed too that those years include two of the severest floods that ever occurred both greater than any on record, such floods as would have previously reduced the revenue much below the former average. Indirectly the works have affected the revenue—

"*First.*—Most materially by the expenditure;

"*Second.*—By the means of transit afforded by the canals to a Delta before unprovided with a single mile of road possible in the monsoon;

"*Third.*—By the additional capital already received through the increased produce and consequent capital thrown into the district, the people are now greatly enriched and able to turn to better account all the advantages they have from rich land, abundance of water, &c.;

"*Fourth.*—And this in a most important degree too by the encouraging stimulus given to the district by the substitution of hope for despondency and also by the excellent effect of employing a large portion of the laboring classes upon a variety of work under European superintendence.

"7. In fact there are a dozen ways in which such an undertaking throws life and e[illegible] a district in the state of hopeless torpor that this was.

"8. I have given this outline of the operations to show the circumstances in which the officers have been placed throughout them. From the beginning to this time it has appeared as if the works were on the point of stopping altogether, notwithstanding the continued success, and the most splendid results such as certainly have never been seen in any province in India yet. It cannot be said that any of these delays were necessary from want of funds, for the works themselves have much more than supplied the funds. Not a rupee has been sent to the district, on the contrary it has paid lacs to the general treasury more than it would have done had no part of the revenue been expended in public works.

"9. What I would now therefore request of Government is that they will at once sanction the money for the present estimate and for others as fast as they can be prepared, unless, of course, the planning of the works appears to them so doubtful as absolutely to require that they should have more satisfaction on that head. I don't expect, however, that they will be refused on this ground, and whatever examination is required to be made on other points can as well be made while the works are under execution.

"10. I take it for granted that the project will certainly be now prosecuted to a conclusion whatever happens. I cannot suppose that the Hon'ble Court will counter-order a work they have actually sanctioned when every possible proof of success is already attained.

"11. Should this point not be considered, I have the honor to request that the Government will be pleased to forward my present remonstrance by this mail to the Supreme Government. The working season has already commenced, so that there is now not a day to be lost, and I feel fully assured that upon this Government's earnest recommendation, the Supreme Government will give it full authority to prosecute the undertaking with vigour and to expend whatever sums are necessary upon it without delay.

"12. I must confess that I have been greatly disappointed in the results of the works in one respect. I thought whatever doubt there might be about so new an undertaking at first, whether as to its execution or its results, we should long before, before we have had such proofs as we have now been favoured with both of their stability and their returns, have had the reward of security that the Government were entirely satisfied on both heads in the perfect readiness with which the estimates for the remaining works were sanctioned and the cordial help given to the officers in every way and especially in not paralysing their arrangements by delay in ordering the necessary funds when they could be paid out of the present profits of the works.

"13. What I wish especially to submit is that the sanctioning of the estimates without delay is quite compatible with any inquiry that the Government may think proper to institute in the matter. The works must be executed so far seems clear, and their being deferred while it will certainly cause additional expense, risk and loss of revenue, cannot, so far as I can see, assist the inquiry respecting what has been done unless, as I have said, the planning is questioned which I do not expect.

"14. I should not omit in this paper to mention that the prosperity of Rajahmundry has now as sound a foundation as possible in a foreign trade of the safest kind. It has now six staple articles of commerce, viz.—

(1) Sugar to England,
(2) Rice to Bourbon, England, and France,
(3) Gram to Bourbon,
(4) Tobacco to various places,
(5) Hemp to England, and
(6) Oil-seeds to England and France.

"15. For all these there is, as it were, an unlimited market and by them the district is connected with rich countries in whose wealth it must of necessity partake by this means.

"16. With respect to the subject of inquiring into the progress and results of the project, I most earnestly request that a thorough inquiry may be made. Perhaps the Supreme Government might approve of a suggestion that an officer should be sent from Bengal, who could see the works himself and examine on the spot their effects upon the district. My disappointment is that too little, not too much, interest has been shown respecting the works. Not a single person of any rank or authority has yet found time to visit the district and thus obtain such a conviction respecting its improvements, as no statements or reports can ever produce."

" *Statment showing the value of goods exported by sea from the District of Rajahmundry from the year* 1843-44 *to* 1850-51.

	RS.
1843-44	6,33,991
1844-45	7,29,287
1845-46	9,06,554
1846-47	13,53,503
1847-48	10,95,397
1848-49	10,56,727
1849-50	9,76,719
1850-51	13,96,226

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"*Statement showing the Revenue, deducting the Expenditure on Public Works, in the District of Rajahmundry.*

Year.	Total Collection.	Expense on Public Works.	Net Revenue.	Increase above average of six years.	Total increase to the end of each year.	Difference between six years' average and each successive year not reckoning expenditure.
	Rs.	Rs.	Rs.			
1835-36 ...	19,83,888	5,654	19,78,234	...	...	...
1836-37 ...	21,43,769	9,017	21,34,752	...	...	...
1837-38 ...	19,94,614	5,948	19,88,666	...	...	...
1838-39 ...	15,54,148	16,917	15,37,231	...	...	...
1839-40 ...	17,13,201	19,772	16,93,429	...	...	...
1840-41 ...	16,38,767	40,833	16,42,933	...	...	...
1841-42 ...	19,23,702	17,166	19,06,586	...	...	...
1842-43 ...	18,77,745	12,258	18,65,486	...	...	...
1843-44 ...	19,86,148	37,858	19,48,289	...	...	...
1844-45 ...	20,37,358	34,187	20,03,170	...	...	...
1845-46 ...	20,91,085	44,734	20,46,350	...	...	...
Average of 6 years ...	19,33,301	...	19,02,136	...	...	...
1846-47 ...	22,19,098	2,44,182	19,74,913	72,776	72,776	2,85,797
1847-48 ...	22,73,485	3,45,561	19,27,844	25,708	98,484	3,40,184
1848-49 ...	23,18,180	2,20,611	20,97,569	1,95,433	2,93,917	3,84,879
1849-50 ...	*22,02,984	2,55,067	19,47,886	45,750	3,39,667	2,69,683
1850-51 ...	24,81,700	3,05,143	21,76,557	2,74,421	6,14,088	5,48,399
1851-52 ...	25,90,000	2,19,571	23,70,429	4,68,293	10,82,381	6,56,699 "

* Year of unprecedented flood in the Godavery by which full a lac of rupees of revenue was lost.

This called forth an angry minute by the Governor, Sir Henry Pottinger, and a Government Order which states that "The Governor in Council has read with surprize," &c., &c., "and regrets that this officer," &c., &c. The same Government Order also declares that the Government is "not prepared to sanction any further outlay except for the completion of works exclusively for the purposes of *Irrigation.*" Indeed, it was scarcely possible that matters should run smoothly. On one hand was the Enthusiast, whose genius and special knowledge enabled him to see clearly that what he proposed to do was in the best interests of Government as well as of the people, and who was impatient of any delay; on the other hand were the controlling powers who held the purse strings, and whose *duty* it was to check too hurried an advance along a path, the issue from which was to them obscure.

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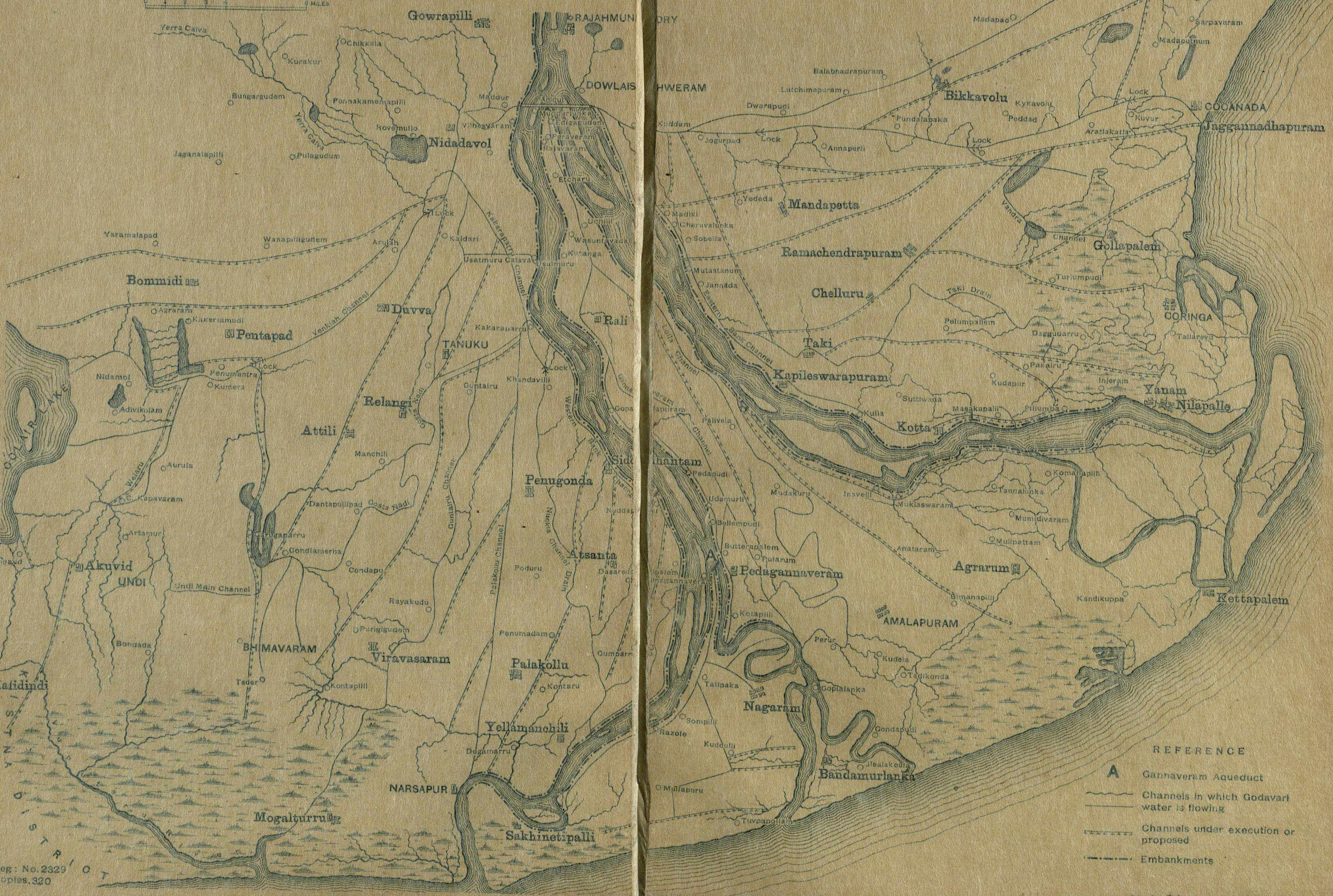
GODAVARI DELTA

Skeleton map showing the Channels existing and proposed –

in 1853

SCALE OF MILES



REFERENCE

A Gannaveram Aqueduct

Channels in which Godavari water is flowing

Channels under execution or proposed

Embankments

Reg: No. 2329
Copies. 320

Photo-Print Survey office, Madras

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The general state of progress about this time as regards the means of utilizing the Anicut water is shown in the accompanying map* prepared by the Civil Engineer, Gódávari District, early in 1853, and to supplement the information which can be gathered from it, the following extracts are given from "A Report of the Chief Engineer (Colonel A. Cotton), dated 23rd February 1853:—

"I left Madras on the 3rd March, and landed at Cocanada on the 7th, and proceeding up the Thooliah Bagah channel in a boat, I met the Civil Engineer on the way, who returned with me to Dowlaisweram. I remained in the district till the 28th, having in the meantime in company with the Civil Engineer navigated the Samulcottah channel, the Eastern main channel as far as the new lock near Alamoor, 16 miles from Dowlaiswaram, the Rallee main channel, and Nuggarum channel to within four miles of the sea, 44 miles; the Western main channel, Weyairoo, Venkiah and Beemarum channels, to near Beemarum in the Woondee talook, 34 miles; and a branch of the Weyairoo to the Colair, crossing which I landed within five miles of Ellore." . . . . .

"With respect to the progress of the works; commencing from the eastward—the Samulcottah channel, which had been stopped short at the outside of the town, has been carried round it, so as to discharge its surplus water into the Yelairoo. As a proof of the use and effect of these channels in navigation, a permanent store has been constructed near the town for the collection of jaggery, from whence it is to be transmitted by the channel to the Rajahmundry sugar works, to which it had formerly to be conveyed by land. The use of this channel for the jaggery, and of the Thooliah Bagah to convey the sugar to Cocanada, will make a difference of more than £1 a ton; a good instance of the effect of communications in helping India to compete with other countries in foreign markets. In the Thooliah Bagah, the new lock and cutting away of the great bend, above 10 miles from its head, has been completed; by which the water has been retained at a higher level, to throw a better supply into the Samulcottah channel, and also into the branch now about to be cut in the opposite side of the Thooliah Bagah. The only work of any consequence now required to this most important line of channel is the opening out of the last two miles by the Kottah Calwah, from the Covoor lock to Cocanada, to avoid the winding and shallow tide-water channel by which the boats at present proceed, and also to convey fresh water to Cocanada. This cut will now be completed. Several new villages have been watered from this channel this year, by branches planned and executed by the Native Superintendent, with a considerable addition of revenue in consequence." . . .

"On the line of the Coringa channel the Alamoor lock has been nearly completed, and the channel cut from it three miles towards Coringa. The continuation of this work with its tunnels and locks, which had been stopped when the Government refused further funds, will now be prosecuted. The officer in charge, however, after the difficulty and confusion caused by the sudden determination of Government to stop the works, was afraid to proceed vigorously with them, lest, when he had collected four or five thousand people, he should again have to disperse them. I urged him to proceed as if he was quite sure of the cordial support of Government, in the hope that before the sum now ordered was expended, they would be satisfied that there was really no ground whatever for stopping or even delaying the works." . . . .

"In the Central delta, the aqueduct has been completed, with the exception of the towing path. The channel above it, which had been almost destroyed by the river breaking in upon it in the flood, has been put in complete order, the main channel leading from it has been continued to tide-water, within four miles of the sea, and several miles of branch channels have been cut. It was highly interesting to pass over this aqueduct in a boat, and see an ample stream of water thus thrown

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* Taken from Baird Smith's '*Irrigation in Madras.*'

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into the richest part of the district, in the height of the dry season, when a year before not a brick had been burnt towards the erection of this large work, 800 yards long, and 28 feet wide. The work was in perfect order, and is used as a bridge, though the side walls are only two feet and-a-half wide. The Civil Engineer purposes only to widen one side of these this year, by a stone coping to render it safe as a foot bridge, which will be sufficient for present purposes, and will leave him at liberty to execute some other work more urgently required. Below the aqueduct the channel soon begins to flow through plantain and sugar gardens; and innumerable temporary sluices have been made in the banks, to lead the water into them. It has reached them in time to admit of a considerable extension of planting of sugar this year. One person had cut his whole crop for plants, and had made no jaggery. A gentleman, who has sugar works on the bank of the channel, informed me that there would be a good deal of additional sugar planted this season. I should mention that, from the posts not being yet carried the whole length of the annicut, sufficient water is not yet thrown into the Rallee main channel fully to supply its dependent channels, and the water in the Naggarum channel is, therefore, in general a foot or less below the level of the ground; so that they still have to raise it a little, to bring it upon the lands immediately adjoining the channel. This will soon be corrected.

"Nothing of any consequence has yet been done for the eastern side of the Central tract, forming the talooks of Rallee and Amlapoor: water is, however, thrown into its old channel the Cowseca, and passes by it to tide-water."

"On the Western side of the Delta the New Works besides the New Lock at Vizeswaram are: the extension of the river bank channel to tide-water near Nursapoor; the completion of the lock near Kakarapurroo, and the clearing of the Nukkalah channel leading from it to Nursapoor; the Palkole channel leading from the Bhoopiah to Nursapoor; the completion of the double lock and calingulah at the end of the Venkiah channel, and of the embankment of that channel; the cutting of the large drainage channel from the Weyairoo at Pipparroo direct to tide-water near Beemarum, and that of the other drainage channels near the Colair. The communication with Nursapoor is not yet completely open. The lock at the lower end of the Nukkalah must be built to make this quite effectual; but when a little more work has been executed in clearing the Nukkalah, the water will be turned into it, and, I am in hopes, will make a practicable navigation. The connection of the port of Nursapoor with the rest of the district is very much required. The same also is the case with the central part of Oondee. The Sub-Collector states, that the want of water communication with Cocanada has been a great drawback to that talook this season. There will soon be one through the middle of the talook. The completion of the Purimillee lock at the end of the Venkiah, is very important: it makes the communication good into the Colair, and the lower part of the Weyairoo.

"A great deal of water is now carried through these talooks, and led to the land by these channels; and the Sub-Collector gives a most satisfactory account of their improvement." . . .

Colair drainage.

"It was highly satisfactory also to me to see so considerable progress made in cutting the great channels for draining the country near the Colair. About a quarter million of cubic yards of earth had already been executed, and about 4,000 people were at work upon them. They will, I hope, be able to complete a million cubic yards this year, and thus open the two main lines to a considerable breadth. This alone will have so powerful an effect, as to relieve this tract effectually, while the rains are moderate; and I have no doubt that it will give a new character to the cultivation of this tract this year, by enabling the people to begin their cultivation much earlier."

From about this time the success of the works became so apparent that money was more readily granted for their development. The chief sanctions, after those stated at the beginning of this chapter, up to 1868–69, will be found in the following statement :—

Year of sanction.	Work.	Amount.
		RS.
1853–54	Widening Samalkot Canal, Eastern Delta	48,227
	Second Supplemental Estimate for Works, Central Delta	15,990
	Widening Main Canal, Excavating irrigation and drainage channels, and building 110 Irrigation sluices, Central Delta	58,403
	Works in the Western Delta	71,382
	'Kadeyapulanka Lock, Coringa Channel' (in portion now known as *Bank Canal*, Eastern Delta). This lock was removed when the 'Completion Estimates' were carried out	9,774
1854–55	Completing the Eastern Branch Channels	1,11,903
	Minor Channels, Eastern and Western Deltas	41,743
	Branch Channel from Velpúr to Mogalturru, Western Delta	5,250
	Drainage Channel from the Gostanadi, Western Delta	7,260
	Ellore Navigation Canal, Western Delta	2,87,644
1855–56	Narsapur Canal, Western Delta	1,13,199
	Minor Irrigation and Drainage Channels, Western Delta	21,000
	Building a tow-path on each side of the Naggaram Aqueduct ...	23,360
1856–57	Canal from Samalkot to Tuni. (This was never carried out) ...	2,34,305
	Navigation Canal, Samalkot to Cocanada ; Eastern Delta	1,17,339
	Supplemental Estimate, Narsapur Canal ; Western Delta	57,280
	Improvement, Undi Canal ; Western Delta	5,550
	Improvement, Akeed Canal ; Western Delta	4,820
	Forty-seven crossing places on the Cocanada and Samalkot Canals ...	5,520
1857–58	Navigation Canal, Dendalúr to Perikeed. (This was an extension of the Ellore Canal sanctioned in 1854–55. Only about 4½ miles of the extension were situated in the Gódávari system, which terminates at Ellore, the remainder forming portion of the Kistna system of Canals. The sanction for the Gódávari portion of this extension amounted to *about* Rs. 45,000)	1,34,835
1858–62	From 1857 to 1862 orders were in force restricting expenditure in consequence of the 'Mutiny' and the only sanctions given were to cover excess expenditure on works previously sanctioned, the more important of these being—	
	Excess expenditure on the Narsapur Canal (Western Delta)...	30,407
	To complete the Lock at the end of that Canal	23,500
	Excess on estimate (Rs. 1,17,339) sanctioned in 1856–57 for Canal, Samalkot to Cocanada	20,937
	Excess on estimate (Rs. 9,774) sanctioned in 1853–54 for Kadeyapulanka Lock	3,311
1862–63	Improvements of Venkiah and Weyéru Canal, and Akeed Canal, Western Delta	80,120
1863–64	Enlarging Mundapetta Canal, Eastern Delta (afterwards included in the 'Completion Estimates')	41,960
	Building Lock and Weir a short distance below the Gunnaram Aqueduct, Central Delta	9,350
	Enlarging the Samalkot Canal, Eastern Delta	84,000
	Supplemental Estimate, Ellore Canal	4,928
1866–67...	Provision for Cross Drainage Works, Ellore Canal	1,04,000
1868–69	Revised Estimate, Samalkot Canal (to take the place of the one for Rs. 84,000 sanctioned in 1863–64). This was afterwards included in the 'Completion Estimates'	1,31,200
	Adding additional cut-stone apron to Vizéswaram Under-sluices ...	9,720

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"Towards* the end of 1866 the Secretary of State had sanctioned the adoption of the general principle of supplementing the ordinary resources of Government by means of loans for the construction of 'Productive Irrigation works.' The expenditure on such works had hitherto been met from 'Ordinary Imperial Funds,' but from this period 'the outlay' was classed under either 'Imperial Extraordinary' and met from 'Loan Funds,' or under 'Imperial Ordinary' and met from current revenue, according as it was incurred on important works requiring the sanction of the Government of India, or on small works sanctioned by the Local Government."

For the desultory patching which had to be resorted to when expenditure was regulated by what might be available year by year from current revenue, it was now possible to substitute a comprehensive project for development and improvement, to carry which to completion funds could with certainty be continuously provided. Advantage was at once taken of this, and estimates were prepared for extension and remodelling of the Gódávari Works to fit them for the increasing demands of Irrigation and Navigation, and for the proper Drainage of the Delta, which had not previously been sufficiently attended to.

These estimates, which were submitted separately for each section of the delta, were called the 'GÓDÁVARI COMPLETION ESTIMATES.' A convenient title, though, of course, not strictly accurate, as from the nature of the case, there could not be absolute finality about such estimates.

The first estimates (for the Eastern and Western Deltas) were sent in by the then Superintending Engineer Captain J. G. Ryves, R.E., in 1869, but they were returned for revision. They were remodelled, the one for the Eastern Delta by Mr. Sage, Executive Engineer, and that for the Western Delta by Mr. J. W. Rundall, Executive Engineer, and were submitted by Major (now General) J. F. Fischer, R.E., then Acting Superintending Engineer, whose reports accompanying them are embodied in P.M.G., No. 2335, dated 28th September 1870, and No. 768, dated 14th March 1871. They were reviewed and to some extent altered by Major (now General) J. Mullins, R.E., then, and for many years afterwards, Chief Engineer for Irrigation, of the Presidency, to whom much of the general excellence of the '*Completion*' Project Works is due.

The '*Completion Estimate*' for the 'EASTERN DELTA,' Rs. 13,14,000,† was sanctioned by the Government of India in May 1871; that for the WESTERN DELTA, Rs. 13,04,640† in August of the same year. The following is a condensed description of what these estimates provided for; the amounts under each head will be found in column 2 of the 'Abstract Comparative Statements' given further on when dealing with the revised estimates.

EASTERN DELTA.

IMPROVEMENTS TO HEAD SLUICE.

Providing proper shutters and gearing; this was carried out in the manner described in Chapter V.

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* *Narrative of the Gódávari Delta system*, paragraph 24.

† Main items will be found in the 'Abstract Comparative Statements' given further on when dealing with the *Revised Completion Estimates*.

MAIN CANAL.

Enlargement to make it capable of carrying, with a velocity of from 1·6 to 1·7 feet per second, the following quantities of water, viz.: as far as head of *Bank Canal* 2,912 cubic feet per second for the total area of 188,170 acres proposed to be irrigated; from there to the *Samalkot Canal offtake*, 1,479 cubic feet per second; thence to the *Mundapetta Canal offtake*, 1,063 cubic feet per second; and from that point, 581 cubic feet per second on to the *Cocanada Canal.*

BANK CANAL.

(*a*) *Earthwork* to fit it to carry the water for irrigation of 40,399 acres, and for the *Coringa Canal* irrigation also, as far as the head of that canal.
(*b*) Four *Second-class Locks* and their *Weirs.*
(*c*) Building one new, and altering one old, *Surplus Weir.*

COCANADA CANAL.

(*a*) *Earthwork* to fit it to carry the water for irrigation of 38,761 acres.
(*b*) Four new *First-class Locks* and their *Weirs.*
(*c*) Twenty miles *Minor Irrigation Channels.*
(*d*) Thirty *Head Sluices to Minor Irrigation Channels.*

SAMALKOT CANAL.

(*a*) *Earthwork* to fit it to carry the water for 27,700 acres.
(*b*) One '*Escape*' or '*Surplus*' *Weir.*
(*c*) Forty-five small *Bridges* over Inlets.
(*d*) *Distributaries*, with their Head Sluices, Culverts, &c.
(*e*) An *Iron Girder Bridge* over the canal at *Médapad* (part of cost was paid by '*Local Road Funds*').

MUNDAPETTA CANAL.

(*a*) *Earthwork* to fit it to carry the water for 32,155 acres.
(*b*) Two *Second-class Locks* and their *Weirs.*
(*c*) *Minor Channels with their Masonry Works* for distribution of water.

CORINGA CANAL (branching from *Bank Canal*).

(*a*) *Earthwork* to fit it to carry the water for 32,257 acres (exclusive of *Injeram Canal*).
(*b*) Altering the *Alamúr Lock.*
(*c*) *New Weir* for *Alamúr Lock.*
(*d*) Twenty miles, *Distribution Channels.*
(*e*) Thirty *Sluices, &c., for Distribution Channels.*

INJERAM CANAL (branching from *Coringa Canal*).

(*a*) *Earthwork* to fit it to carry the water for 16,897 acres.
(*b*) *Tidal Weir* at end of canal.
(*c*) *Minor Channels and Masonry Works.*

BICCAVOLE DRAIN.

Improving, to convey to the Yeléru near its end, the upland drainage passed across the *Samalkot Canal* and the surplus from that canal and its Irrigation.

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TULIABAGA DRAIN.

When the delta works were first carried out, a considerable portion of the original Tuliabaga was incorporated in the *Cocanada Canal*, leaving the country which the Drain, even in its natural state, served but imperfectly, worse off than before. This estimate provided for making an almost entirely new channel to efficiently drain the tract between the *Cocanada* and *Coringa* Canals and for a *Surplus Weir* into the drain at its head from the Cocanada Canal.

TAKEE DRAIN.

The *improvement and considerable enlargement* of a natural tortuous and inefficient channel for drainage of the tract between the *Mundapetta*, *Bank* and *Coringa* Canals (the surplus water from which is taken under two aqueducts on the last-named Canal), and also for the whole of the area enclosed by the *Coringa*, *Bank* and *Injeram* Canals.

REST-HOUSES.

Five *Buildings*, primarily for the use of Canal officers when on inspection duty.

WESTERN DELTA.

IMPROVEMENTS TO HEAD SLUICE.

Providing proper shutters and gearing; this was carried out in the manner noted in Chapter V.

MAIN CANAL.

Improving the portion known as the '*New Apparao Chord-line*' so as to facilitate navigation and enable it and the '*Old Apparao Channel*' to carry in all 3,945 cubic feet per second.

KAKARAPARRU CANAL.

Improving so as to fit it to carry without too great velocity for navigation 1,650 cubic feet per second for 1¾ miles to the *Gostanadi* head, and beyond that, 1,200 cubic feet per second to its end, where it bifurcates into the *Bank* and *Narsapur* Canals.

GOSTANADI AND VELPÚR CANAL.

(*a*) Improving the natural drainage for about 14½ miles.

(*b*) There building a *Weir* near Velpúr across the Gostanadi to hold up the water so as to reduce the surface fall for navigation to about 6 inches a mile, with a capacity for irrigation water of 450 cubic feet per second.

(*c*) Making a *cut* from above the weir to an existing 'Velpúr' Irrigation Channel, and *improving that channel* for 15 miles to the Baswaraokodu, so as to make it navigable to that point and capable of carrying water for 36,200 acres.

(*d*) One *Second-class Lock* and *Weir* at the Gostanadi head and another *Lock* and Weir at *Penumantra* about 21 miles from the head. (This Lock and Weir were built at Mamudúr about 2½ miles further down.)

(*e*) An *Aqueduct* to carry irrigation water over the Baswaraokodu, with a *Surplus Weir* and *Drop* below it. (These were never built being superseded by other arrangements under the revised estimate.)

(*f*) A *Surplus Weir* near the Rozukodu.

(*g*) *Minor Masonry Works.* (The arrangements at end of the Velpúr Canal were much altered in the revised estimate.)

BANK CANAL.

(*a*) *Earthwork* to fit it to carry the water for 23,800 acres (starting at its head with 337½ cubic feet per second), and to make it navigable to its then intended end at Dodipatla, about 23 miles from its head.

(*b*) Three *Second-class Locks* with their *Weirs*, at Khandavelli, Kodér, and at the then intended end of the canal, dropping it to the Gódávari, where tidal, near Dodipatla.

(*c*) A *Surplus Weir* into the 'Nakkala' in the second mile of the canal.

(*d*) *Minor Channels with Masonry Works* for distribution.

NARSAPUR CANAL.

(*a*) *Earthwork* for extending the canal for both Irrigation and Navigation from Narsapur to a tidal creek near Mogalturru.

(*b*) Six *First-class Locks* (one of them a tidal Lock at the end) with their *Weirs.*

(*c*) *Minor Channels with Masonry Works* for distribution.

ELLORE CANAL.

(*a*) *Earthwork* to fit it to carry the water for 48,200 acres (exclusive of the '*Attili Canal*' which branches from it a short distance below its head) and for making proper towing paths to facilitate navigation.

(*b*) Two *Large Distributaries* known as the '*Mid*' and '*Low*' *Level Channels* *; the former Rs. 64,180 and the latter Rs. 19,290.

(*c*) Three large *Drainage Channels*, known as (1) '*Pandikodu Drain*' (Rs. 59,530), (2) '*Drain from 9½ miles of Mid Level Channel*' *and Sundry drains*, (Rs. 24,000), (3) 'The Drainage Diversion' (Rs. 21,700).

ATTILI CANAL (branching from *Ellore Canal*).

(*a*) *Earthwork* to fit it to carry near its head the water for 34,330 acres, and to be navigable as far as the large village and market of Attili.

(*b*) Two *Second-class Locks* and their *Weirs.*

(*c*) *Surplus Weir* at 10 miles down the Canal capable of discharging 225 cubic feet per second into the Gostanadi below the Velpúr Weir.

(*d*) *Minor Channels* with *Masonry Works* for distribution.

JUNCTION CANAL.

(*a*) *Earthwork* to make a navigable canal from the *Ellore* Canal to the *Venkiah* and *Weyéru*, taking also the irrigation water for the 'Mid' and 'Low' Level Channels as far as their heads.

(*b*) *Double, First-class, Lock* and *Weir* at Madhapuram.

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* Now take off from the 'Junction Canal.'

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(*c*) *Head Sluices* to 'Mid' and 'Low' Level Channels (afterwards transferred to Ellore Canal Estimate).

Venkiah and Weyéru Canals and Akeed Canal.

(*a*) *Earthwork* required to improve navigation.
(*b*) Improvement of *Surplus Weir* above Perimella Lock.
(*c*) *Minor Masonry Works* for distribution channels.

Undi Canal (branching from the Venkiah).

(*a*) *Earthwork* to fit it to carry the water for 58,900 acres and to make it navigable as far as the large village and market of Undi.

(*b*) *Head Lock* (second class) with *Weir* at head of canal, and *Lock* (with *Weir*) into the Yennamaduru drain 11½ miles down the canal. (This latter Lock with *Weir* was not built, but instead of it a *Lock* and *Weir* were built at 7¾ miles from the head to reduce the fall in the canal—*see* revised estimate.)

(*c*) *Two Surplus Weirs.*
(*d*) *Channels* with their *Masonry Works* for distribution.
(*e*) *Minor Drainage Channels.*

Nakkala Drain (between Bank and Narsapur Canal).

A large *Outfall Sluice*, to prevent the Gódávari when in flood backing up the drain, combined with an aqueduct for carrying irrigation water from the Bank Canal across the Nakkala to a considerable area on its right bank.

Mogulturu Drain.

Earthwork to fit it for carrying off the drainage between the Narsapur Canal and one of its large distributaries, the Jinnúr Channel.

Gostanadi Drain.

Earthwork to convert the Baswarakodu into a new outfall for most of the discharge of the Gostanadi, and a large *Outfall Sluice* to pass the remainder into the Yennamaduru, and prevent that stream when in flood from backing up the Gostanadi; estimated to cost in all Rs. 94,000. (This was superseded by arrangements noted in the revised estimate under the head of 'Gostanadi and Velpúr Canal, and by the improvement of the Gontér Drain lying between the Narsapur Canal, and the Gostanadi.)

Yennamaduru Drain.

(*a*) *Earthwork* for raising and strengthening the banks.

(*b*) *Masonry Inlets* for branch drains. (This is the chief outfall for the Yerrakalwa or Weyéru—*see* Chapter VIII.)

Other Drains.

Improvements of various drainages, the more important being—

(*a*) The *Bondáda Drain* between the Undi Canal, the Venkiah and Weyéru, and the Akeed Canal.

(*b*) '*Kaza Drain*' between the Nakkala and the Narsapur canal.

(*c*) '*Baggéswaram drain*,' a large affluent of the Gontér Drain.

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Directly these estimates were sanctioned, the work was undertaken and carried on continuously to completion; the expenditure from year to year will be found in Appendix No. I.

In 1882 the 'Completion Estimates' for the CENTRAL DELTA were ready, and it was decided that together with them should be sent revised estimates for the *Eastern* and *Western* deltas, as in the ten years during which the works had then been in progress, some modifications of the original intentions had been found advisable. The complete estimates for the whole system were collated and sent in by Colonel J. Hasted, R.E., in a very thorough manner with his report of 7th March 1882, which, with all its accompaniments, will be found in P.M.G., No. 259 I., dated 21st March 1882. They were reviewed by Colonel (now General) J. Mullins, R.E., who was still Chief Engineer for Irrigation, in a 'Note' of 14th March 1882 (which will be found in the same P.M.G.) and were sanctioned by the Secretary of State in his despatch of 17th August 1882, of which the following is a copy:—

"*Despatch from the Most Honourable the Secretary of State for India, to His Excellency the Most Honourable the Governor-General of India in Council, dated India Office, London, 17th August* 1882, *No.* 42, *Public Works.*

"I have received and considered in Council your Excellency's Public Works letter, No. 32, of 17th June last, submitting for my sanction a complete revised estimate of the cost of the Gódávari Delta System of Irrigation and Navigation Works, which has been prepared by the Madras Government in compliance with the directions contained in my Public Works Despatch, No. 24, dated 4th August 1881.

"2. The complete estimate now submitted is in supersession of all former sanctions, and provides for the thorough completion of the whole system of the Gódávari Delta Works, as at present contemplated.

"3. The total cost of the works is estimated to be Rs. 1,30,32,653, of which Rs. 1,10,88,695 is for direct, and Rs. 19,43,958 is for indirect charges.

"4. Of this total, Rs. 1,06,47,713 has already been expended up to the end of 1880–81, leaving Rs. 23,84,940 for outlay subsequent to that date.

"5. The total net revenue realized to the end of the year above mentioned, after meeting all working and interest charges, was Rs. 1,38,41,571, and it is expected that, on the completion of the works, the system will yield a net return of 12·7 per cent. per annum on the capital outlay.

"6. I accord my sanction to the estimate now submitted, and, considering the satisfactory nature of the present and probable future results of the undertaking, there can be no doubt that it has been rightly classed as a Productive Public Work, and that the additional outlay proposed for the completion of the undertaking is well justified.

"7. The Irrigation and Navigation Works of the Gódávari Delta may well be a subject of congratulation to your Government, and I fully join in the opinion expressed by the Government of Madras, that the usefulness of this most successfully executed project, the development of which has been steadily going on during the last 35 years, is by no means to be measured by the direct pecuniary returns only, large as they have been. The present flourishing condition of the Gódávari District, and the vast improvement it has undergone since the construction of the works, which provide for the irrigation of nearly 600,000 acres, afford the best possible evidence of the great benefits conferred on the people."

How the Rs. 1,30,32,653 of this sanction is arrived at will be seen from columns 1 and 2 of the Statement printed on pages 114, 115.

CSL

The comparison as to cost between the original 'Completion Estimates,' above described, of the *Eastern* and *Western Deltas*, and the 'Revised' Estimates is given in the following Abstract Comparative Statements :—

Estimates.	Original.	Revised.	Increase.	Decrease.
1	2	3	4	5
EASTERN DELTA.	RS.	RS.	RS.	RS.
Head-sluice, Main Canal	17,890	12,538	...	5,352
Main Canal	28,060	26,794	...	1,266
Bank Canal	2,33,200	3,04,466	71,266	...
Cocanada Canal	1,93,345	2,17,501	24,156	...
Samalkot Canal (includes the sanction of 1868–69 for Rs. 1,31,200)	1,35,400	1,57,274	21,874	...
Mundapetta Canal	77,373	58,352	...	19,021
Coringa Canal	80,843	77,860	...	2,983
Injeram Canal	31,323	37,040	5,717	...
Tuliabaga Drain	1,50,966	1,47,768	...	3,198
Biccavole Drain	71,300	70,370	...	930
Takee Main Drain	2,84,300	2,44,275	...	40,025
Rest-houses	10,000	13,550	3,550	...
Unforeseen works	...	52,212	52,212	...
	13,14,000	14,20,000	1,78,775 72,775	72,775
Total, Increase	...	...	1,06,000	...
WESTERN DELTA.				
Head-sluice, Main Canal	19,500	14,861	...	4,639
Main Canal	49,000	39,729	...	9,271
Kakaraparru Canal	34,375	57,850	23,475	...
Gostanadi and Velpúr Canal	1,40,360	1,37,316	...	3,044
Gostanadi Extension	...	81,404	81,404	...
Bank Canal	1,07,900	1,45,549	37,649	...
Narsapur Canal	2,08,925	2,18,224	9,299	...
Ellore Canal	2,46,590	2,79,251	32,661	...
Attili Canal	86,000	81,891	...	4,109
Junction Canal	83,610	75,428	...	8,182
Venkia and Weyéru	11,960	29,439	17,479	...
Undi Canal	1,10,700	1,44,550	33,850	..
Nakkala Drain	13,200	22,700	9,500	...
Mogalturru Drain	18,320	24,309	5,989	...
Gostanadi outfall and Sluice	94,000	...	...	94,000
Gonter Drain	...	24,500	24,500	...
Yennamaduru Drain	28,800	27,602	...	1,198
Other Drains	28,200	51,699	23,499	...
Rest-houses	23,200	22,739	...	461
Unforeseen works	...	50,959	50,959	...
	13,04,640	15,30,000	3,50,264 1,24,904	1,24,904
Total, Increas	...	...	2,25,360	...

In the case of the EASTERN DELTA the chief *Increases* are due to—

First—Provision under each canal of *Quarters* for the Lock Establishments to live in, Rs. 20,660.

Second—*Extension of the Bank Canal* to tide water in the Coringa river, Rs. 58,750.

Third—Provision for unforeseen works, Rs. 52,212.

The chief *Decreases* are due to—

First—Retention in the Mundapetta Canal of the *Pasalapúdi Lock and Weir*, instead of building new ones.

Second—Reduction of width originally proposed for the Téki drain. (A *Surplus Weir* was in the *revised estimate provided* at the head of the Drain, from the Coringa Canal above Alamúr Lock.)

In the case of the WESTERN DELTA, the chief *Increases* are under—

First—*Kakaraparru Canal.*—

(*a*) New head to the Canal.

(*b*) Two Tunnels to take drainage under the Canal.

(*c*) Minor distributaries and drains.

Second—*Gostanadi and Velpúr Canal.*—Extension as a Navigable Canal for 5¼ miles to tide water near the mouth of the Yennamaduru drain. This extension superseded the arrangements originally provided for under the head of the Gostanadi and necessitated the following extra Masonry Works, viz.—

(*a*) Two *Second-class Locks*, one of them tidal.

(*b*) One *Lock Weir*.

(*c*) One *Small Aqueduct*.

(*d*) One *Girder Bridge*.

(*e*) *Various small channels and masonry works.*.

Third—*Bank Canal.*—

(*a*) New Head.

(*b*) Continuing the canal for about 3¼ miles further than was intended to Latchmipalem where the Nakkala joins the Gódávari.

(*c*) Substitution of a *Lock* (second class) and *Weir* at Sidhantam for new lock originally proposed at Khandavelli.

(*d*) Great cost (Rs. 55,021) of the *Tidal Lock* and its *Weir* at Latchmipalem compared with the original estimate (Rs. 36,850) for similar works at Dodipatla. This increase is chiefly due to the difficulty in getting in the foundations of the works, the sub-soil having proved of the most treacherous description.

Fourth—*Ellore Canal.*—

(*a*) Extra provision for passing cross drainage. (Much information as regards this cross drainage will be found in P.M.G., Nos. 401 I., dated 21st June 1880, and 314 I., dated 1st April 1882.)

Fifth—*Undi Canal.*—A much more complete provision for works of distribution. (The alteration in position of Locks has been noted above when dealing with the original estimates.)

Sixth—A provision of an extra Rs. 23,499 under *Other drains*.

Seventh—*Lock Establishment Quarters.*—Rs. 27,040 not provided for in the original estimates, but in the revised ones distributed amongst the various canals.

Eighth—Provision of Rs. 50,959 for *Unforeseen Works*.

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The chief *Decrease* is the Rs. 69,500 due to the alteration in the arrangements first proposed at the end of the Gostanadi drain. The intention of making the Baswaraokodu into an outfall which would carry most of the flood waters of the Gostanadi and of building a large sluice at its junction with the Yennamuduru was given up, and the arrangements noticed under the revised estimates for the Gostanadi and Velpúr Canal, and some minor improvements of the 'Gontér' and 'Baswaraokodi' drains were substituted.

The Abstract Estimates for the CENTRAL DELTA were—

	RS.
Main Canal	54,218
Gunnaram Canal	3,16,120
Bank Canal	1,73,320
Amalápuram Canal	1,65,980
Bendamúrlanka Canal	66,070
Kunavaram Drain	14,000
Gorinkala Drain	30,433
Lower Kowsika Drain	50,600
Minor drainages	8,700
Unforeseen Works	40,559
Total ..	9,20,000

The general provisions of these estimates may be thus summarized:—

MAIN CANAL.

(*a*) Providing *Shutters and Gearing* for the Head Sluice. (The rebuilding of the sluice, which was charged to 'Revenue,' has been noticed in Chapter V.)

(*b*) *Earthwork* to enable the canal to carry 1,745 cubic feet per second of water to irrigate 1,22,420 acres, and to improve its navigation.

GUNNARAM CANAL.

(*a*) *Earthwork* to fit it to carry the water for 47,880 acres, to make its navigation better, and to extend it as a navigable canal to the Gódávari where tidal near Sakinetipalli.

(*b*) Five *Second-class Locks* and their *Weirs.*

(*c*) *Improving the Weir* at the Head of the Canal.

(*d*) Three *Surplus Weirs.*

(*e*) Improving the *Gunnaram Aqueduct* (Rs. 21,700 *) by "bringing † the bed to a uniform slope and plastering with cement the sides, raising the side walls to + 23·81 to allow of still water navigation being maintained in the reach. Improving the tow-paths and railing and making additional recesses for the convenience of foot-passengers."

(*f*) *Distributaries with their masonry works.*

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* Exclusive of a contribution paid for by 'Local Funds' for improvement of pathways over the work.

† Paragraph 17 of Colonel Hasted's report with the estimates.

Bank Canal.

(*a*) *Earthwork* to fit it to carry the water for 29,650 acres, and to make it navigable for 34½ miles. (It was then only imperfectly so far a short distance.)

(*b*) Four *Second-class Locks* and their *Weirs.*

(*c*) Five *Inlets* and one *Tunnel* to admit and pass cross drainage.

(*d*) *Distributaries with their masonry works.*

Amalápuram Canal (branching from the Gunnaram Canal near its Head).

(*a*) *Earthwork* to fit it to carry the water for 31,350 acres (exclusive of 12,540 under its branch the Bendamúrlanka Canal), and to continue it as a navigable canal to 8 miles below Amalápuram.

(*b*) Improving three existing *Locks* and *Weirs.* (One of these weirs was destroyed and a new one built.)

(*c*) One new *Second-class Lock* and *Weir.*

(*d*) Three *Surplus Weirs.*

(*e*) *Distributaries with their masonry works.*

Bendamúrlanka Canal (branching from Amalápuram Canal).

(*a*) *Earthwork* to fit it to carry the water for 12,540 acres and to extend it as a navigable canal along the left bank of the river to tide water near Bandamúrlanka.

(*b*) Two *Second-class Locks* and their *Weirs.*

(*c*) *Distribution Channels with their masonry works.*

Note.—The river encroached to such an extent, along most of the distance where this canal was to run, that the intention of making it navigable was given up, and the works required for that purpose were not carried out. The estimate was in 1889 reduced to Rs. 17,000—*see* P.M.G., No. 445 I., dated 14th September 1889.

Kunavaram Drain.

To pick up and carry to tide water various minor drains lying between the lower portions of the Amalápuram and Bank Canals.

Gorinkala Drain.

Provides for the drainage between Amalápuram, Gunnaram and Bendamúrlanka Canals.

Lower Kowsika Drain.

Provides for drainage between the Amalápuram and Bendamurlanka Canals.

The comparison between the *areas to be irrigated,* as provided for in the Original and Revised 'Completion Estimates,' is given in the following 'Abstract Water-Distribution Statement,' to which has been added the areas of 'first' and 'second' crops actually irrigated in 1893–94 :—

Abstract Water-Distribution statement accompanying revised 'Completion Estimates' of 1882.

Names of Canals.	Area proposed to be irrigated in original completion estimates.	Area proposed to be irrigated in revised completion estimates.	Discharge, &c., proposed in revised completion estimates.		Area actually irrigated, or charged as irrigated, during **1893-94.**	
			In cubic feet per second.	Number of acres to be supplied by 1 cubic foot per second.	First crop.	Second crop.
	First crop only.					
EASTERN.	ACS.	ACS.			ACS.	ACS.
Main—(Direct)	...	200	3	66	622	...
Bank	40,399	20,000	606·48	33	24,917	2,895
Coringa	32,257	32,000	483·85	66	33,099	2,540
Injiram	16,897	16,800	253·45	66	15,439	2,633
Cocanada	38,761	44,000	581·41	75	* 46,658	* 6,843
Sámalkót	27,701	29,000	415·51	69	28,625	2,915
Mandapet	32,155	28,000	482·32	58	31,867	7,642
Total, Eastern Delta ...	188,170	170,000	2826·02	60	181,227	25,468
CENTRAL.						
Main—(Direct)	95,000	1,000	15	66	23	627
Gunnavaram		47,880	681	70	40,514	4,355
Bank		29,650	423	70	34,998	2,007
Amalapuram		31,350	447	70	30,835	2,511
Bendamurlunka ...		12,540	178·99	70	10,692	39
Total, Central Delta ...	95,000	122,420	1744·99	70	117,062	9,539
WESTERN.						
Main—(Direct)	...	1,000	12	83	1,194	80
Kakaraparru	6,000	8,500	103·5	82	9,413	3,805
Gostanadi and Velpur ...	36,200	39,000	487·5	80	42,567	4,669
Bank	23,800	28,000	294	95	35,068	12,412
Narsapur	56,500	59,000	765	77	67,036	9,613
Ellore and Junction ...	48,200	55,000	682·5	80	57,897	3,828
Attili	34,200	33,000	475·5	69	31,884	9,073
Venkayya and Weyeru and Akid.	32,500	48,080	513	93	44,538	1,247
Undi	58,900	48,000	612	78	52,858	1,262
Total, Western Delta ...	296,300	319,580	3,945	81	342,455	45,989
Grand Total ...	579,470	612,000	8516·01	...	640,744	80,996

* Includes Kovúr-Manjair Canal.

It has been thought sufficient to give merely a condensed abstract of what the 'Completion Estimates' provided for; the complete details can be ascertained by reference to the P.M.G., Nos. 259-60 I., dated 21st March 1882, and the statements therewith.

No useful purpose would be served by following the execution of these works year but year; but from the 'Statement of Expenditure on Capital Account,' Appendix No. I, may be seen what was the expenditure on them in each year.

The Government of India having ordered that the "Construction Estimates for the Gódávari Delta be closed from 31st March 1890," a Report on the subject was submitted with P.M.G., No. 365 I., dated 23rd April 1891, from which the following are extracts :—

"8. A general scheme, known as the 'completion project,' for improvement and development of the drainage, irrigation, and navigation, of the Eastern and Western sections of the delta was submitted in 1871; that for the Central section followed eleven years after.

"9. The sanctions for these so-called 'completion projects' were—

	Estimate of 1871.	Revised estimate, 1882.
	RS.	RS.
Head works	...	6,300
Eastern Section	13,14,000	14,20,000
Western do.	13,04,640	15,30,000
Central do.	None	9,20,000
	Total, 'Works' only ...	38,76,300

"10. It is the completion of these works that is now reported and the actual cost as compared with estimate has been—

	RS.
Sanctioned estimate	* 38,62,973
Actual	† 37,56,174
Saving ...	1,06,799

"11. These works carried out since 1872 have provided the delta with efficient drainage; they have *added* nearly 150,000 acres to the irrigated area besides improving the distribution to that existing before; and they have remodelled and extended the navigable canals, connecting them at six extra places with tide water and so bringing great extra lengths of river and tidal creeks into the navigable system.

"12. The comparison between the forecasts, which accompanied the estimates sanctioned in 1882, and the actuals is shown in the accompanying statements ‡ A and B. It will be seen that the *area* now irrigated exceeds the 'ultimate' anticipated, whilst the differences as regards *revenue* and *expenditure* result in the *net* actual revenue falling short of the anticipated by Rs. 35,869, or only 2·17 per cent.

"13. But though there is this close agreement as regards the *net* total revenue, there is a considerable difference between the total *estimated* 'direct and indirect annual charges' (exclusive of "collection" charges) and the *actual*; the estimate was Rs. 3,06,000, the actual is in 1889-90 Rs. 5,00,434. The former sum was arrived at by taking 8 annas an acre of expected ultimate area of irrigation, whilst the latter amounts to 13 annas per acre of first crop or 12 annas per acre of both first and second crop; but it must not be forgotten that

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[*] Differs slightly from above owing to modifications after 1882.

[†] Inclusive of the expected cost (Rs. 69,880) in the revised schedule sanctioned in G.O., No. 268 I., dated 9th March 1891.

[‡] Extracts for 1889-90 only, now printed.

in the sum which gives this rate are included the charges for the various lock establishments and other expenses due to the maintenance of navigation on some 500 miles of canal—expenses which cannot be correctly arrived at ; indeed, when, as in this case, irrigation and navigation are combined and the works and expenses of maintenance are interwoven, it is not advisable that there should be any attempt at separation.

"14. It may be accepted that the forecast of annual working expenses was considerably too little and that the works as a whole will not be kept in good order for less than a yearly expenditure of between 4½ and 5 lakhs exclusive of the arbitrary 'collection charges.'

"15. The following extract from the Administration Report of 1889–90 gives the main facts as regards the irrigation and direct returns of these Gódávari works from their commencement :—

"*Gódávari delta system.—Financial results.*—The following statement shows the financial results :—

Receipts.	During 1889–90.	To end of 1889–90.	Expenditure and Charges. Revenue Account.	During 1889–90.	To end of 1889–90.
	RS.	RS.		RS.	RS.
Irrigation revenue.	20,77,555	454,83,083	Direct charges *...	4,75,360	114,43,627
Share of enchanced land revenue ...	1,55,620	48,15,678	Indirect do. ...	33,574	7,50,771
			Collection charges in the Civil Department ...	1,05,459	31,12,072
Direct receipts in the Public Works Department	1,14,912	16,92,654	Interest charges...	4,31,876	99,82,397
	23,48,087	519,91,415	Total expenditure and charges ...	10,46,269	252,88,867
Deduct portion of revenues assumed to be due to 'old irrigation' less assumed old maintenance charges of Rs. 8,500 a year ...	1,15,500	33,17,524	SURPLUS REVENUE, NET	11,86,318	233,85,024
Net Total ...	22,32,587	486,73,891	Total ...	22,32,587	486,73,891

"'The net revenue from the system during the year, after paying interest charges, was 9·33 per cent. on the capital outlay, 'direct' and 'indirect.' The anticipated ultimate return was 9·3 per cent. per annum on the capital outlay.

"'*Synopsis of results.*—The following is a synopsis of the results of the system :—

		ACS.
(1) Area charged as irrigated—		
First crop	Total	618,649
	Assumed old irrigation	152,000
	New irrigation due to works	466,649
Second crop		53,590
(2) Net revenue in, 1889–90 after deducting interest and all charges—		
Total		13,01,818
Portion taken as due to the works carried out since capital and revenue accounts have been kept, *exclusive* of what is assumed to be due to 'old irrigation works'.		11,86,318

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*'Extensions and Improvements,' 'Maintenance and Repairs,' 'Establishment' and Tools and Plant'—*see* Statement B.

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	RS.
(3) Accumulated *net* surplus revenue (exclusive of all that assumed to be due to '*old* irrigation works') to end of 1889-90	233,85,024
(4) Total *expenditure* on 'CAPITAL ACCOUNT,' both direct and indirect, which has secured the results shown above ...	127,19,245
(5) Year from which amounts against items (3) and (4) commenced to be calculated	1848-49.'

"16. It will be seen that there are 152,000 acres of assumed old irrigation, from which the works get no returns,* and it is but right to call attention to the fact that, whereas the supply to the 'old irrigation' was extremely precarious, it is now certain, and there is also no doubt that rights to irrigation free of charge, the lands enjoying which are locally known as '*mamul pallam*' or 'customary wet,' were granted with too lavish a hand.

"17. Notwithstanding this, the direct annual surplus revenue, after paying *all* charges, including interest at 4 per cent.† on *all* capital expended, is Rs. 11,86,318 or 9·33 per cent. on total outlay, whilst, if interest be not charged, and it must be remembered that the *capital on which it is charged has been repaid more than twice over*, the annual surplus becomes Rs. 16,18,194, the total accumulated surplus Rs. 3,33,67,420, and the profit 12·70 per cent.

"18. But these *direct* returns by no means represent the full value of the works to the State. On this subject Colonel Mullins in his note with Proceedings of the Madras Government, No. 259 I., dated 21st March 1882, said—

"'OTHER VALUABLE RESULTS NOT INCLUDED IN THE ACCOUNTS.—These figures, however, do not by any means represent the full value of the Gódávari delta system even to the State.

"'*First*—There is land not now irrigated, but cultivated with dry crops, which could not have been so cultivated unless first rendered fertile by irrigation and drainage, and cheap means of carriage have made cultivation profitable, which, under less favourable conditions, would not have been possible. The Superintending Engineer has obtained from the office of the Board of Revenue the information given in statement I, from which it appears that the average land revenue of the district for the four years prior to the commencement of the

	Delta taluk.	Upland taluks.	Total.
	LAKHS.	LAKHS.	LAKHS.
delta works was, 1842-43 to 1845-46	5·896	11·603	17·499
For the five years 1873-74 to 1877-78 it was	30·867	11·522	42·389.

The particulars for the years 1878-79 to 1880-81 are not given separately for the deltaic and non-deltaic portions of the district, but, as the revenue of the latter has been for many years between 11 and 12 lakhs, it is probable that the following figures are approximately accurate :—

Years.	Delta.	Upland.	Total.
	LAKHS.	LAKHS.	LAKHS.
1878-79	34·017	11·600	45·617
1879-80	34·635	11·600	46·235
1880-81	31·805	11·600	43·405

The delta for the last year has been shown above as credited with 18·603 lakhs, while the increase in the revenue from the delta taluks is nearly 26 lakhs and the

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* Beyond a paltry Rs. 4,000 or so for estimated 'saving on remissions.'

† The 4 per cent. is charged on Rs. 1,07,60,754, expenditure to end of 1888-89, and 2 per cent. is charged on Rs. 72,308, the expenditure of the year.

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revenue from the upland taluks has been almost stationary. Evidently, therefore, some considerable part of the 7 or 7½ lakhs increase in the delta, which is not included in the accounts of the system, is due thereto.

"'*Secondly*—The trade statistics indicate clearly that the State must have benefited materially by receipts from customs, stamps, and probably from increased consumption of salt. The following abstract shows the growth of the import and export trade exclusive of bullion and specie:—

Periods.	Value of		Remarks.
	Imports.	Exports.	
	LAKHS.	LAKHS.	
1845-46, the year prior to commencement of the delta works	3·887	9·078	
Average of years 1846-47 to 1850-51	4·250	11·747	
Do. do. 1851-52 to 1855-56	3·730	16·629	
Do. do. 1856-57 to 1860-61	6·279	31·061	
Do. do. 1861-62 to 1865-66	9·800	51·602	
Do. do. 1866-67 to 1870-71	18·182	68·343	
Do. do. 1871-72 to 1875-76	17·563	79·444	
Do. do. 1876-77 to 1880-81	24·028	100·650	
1881-82	22·002	124·733	These entries are now added, 25 March 1891. (Intld.) G.T.W.
1882-83	27·054	126·681	
1883-84	24·850	140·995	
1884-85	28·032	147·137	
1885-86	23·111	125·632	
1886-87	24·081	93·933	
1887-88	35·767	117·558	

"'THE DELTA SYSTEM TREATED AS, BUT MUCH MORE THAN, A COMMERCIAL CONCERN.—That the people are not over-taxed may be deduced from above trade statistics, and, yet in addition to the State revenue paid by them, there is the Local Fund cess, by means of which the land communications have been greatly improved, and, in parts, it may be said, created, while education and sanitation have been advanced and hospitals have been introduced. The delta system has been largely concerned in the provisions of ways and means for these improvements. In the accounts it is treated as a commercial concern, but it is far more than that. A commercial company would have made much more out of the delta than the Government have thought it desirable to exact. In the famine years, for instance, when the prices of agricultural produce were so high, and the extra profits made in this delta must have been about three-quarters of a million sterling, a company would have secured, and would have been justified in taking, a good share of the profit by raising the water-rates. Perhaps half a million sterling additional might have been obtained by a commercial company, while high prices ruled without pressing hardly on the agricultural population of the delta. A railway profits in times of famine or scarcity very greatly and directly by increase of traffic. A Government irrigation system gets but a small share of the profits which result from the increase of the demand for food-grains. Its profits are confined to the increase of revenue due to extension of area, while of the increased value of produce it obtains no part. It differs therefore in very important essentials from any commercial concern.' . . . .

"19. As regards 'the probable results of the project when completed,' asked for by the Government of India, it may be pointed out that the 'Project' is virtually completed, that growth of irrigation and revenue has kept full pace with the works, and that more than the anticipated ultimate area has been already brought under irrigation, whilst the area now reached may be taken as approximately the limit to which the river can with certainty supply water, unless, of course, reservoirs be constructed somewhere in its upper reaches to supplement its flow when in the irrigation season its natural supply falls low, as is now often the case. The probable future results, therefore, are not likely to differ considerably from those already reached and stated above, unless indeed, the charge for water be enhanced, and it appears not impossible that in a few years this may be the case, for the matter is under consideration and has been thus dealt with in letter No. 51, dated 26th January 1891, in the Revenue Department to the Government of India:—

"'(5) As regards the water-rates in the two northern districts of Kistna and Godávari, I am to observe that they are believed to be capable of considerable enhancement, but that, as no alteration can be made in them during the currency of the present settlements, the question will be considered at the next revision of settlement, which will take place within the next five or six years.'

"20. But whether another lakh or two of direct revenue be raised or not, there can be no doubt as to the brilliancy of the results of works which raise year after year with certainty upwards of 670,000 acres of wet crops, where before there were but 152,000 acres of uncertain irrigation,—which have created 500 miles of excellent navigable canals in a country which previously had positively no inland communication except foot-paths,—which have already returned a surplus revenue over and above all expenditure and charges for interest of Rs. 1,06,65,779, and give 9·33 per cent. a year in all expenditure and charges, or 12·70 per cent. if interest be not calculated on capital long since repaid,—and which have converted the Godávari collectorate from a poverty-stricken burden to the State, into one of the most prosperous and remunerative districts in the Madras Presidency or, indeed, in the whole of India."

"CHEPÁK,
"25th March 1891.

(Signed) G. T. WALCH,
Chief Engineer for Irrigation."

(Here follow extracts from the statements which accompanied the above Report.)

GÓDAVARI DELTA.

A.—Statement showing for 1889–90 *actuals as compared with the forecast No. III of revenue and working expenses, which accompanied the delta completion estimates sanctioned by the Secretary of State in his despatch No.* 42 *(Public Works), dated 17th August* 1882, *printed with G.O., No.* 854 *I., dated 23rd October* 1882.

Year.	Irrigated area at end of year.			Revenue receipts and charges, both irrigation and navigation.													
	Estimated.	Actual.		Gross revenue due to works.								Charges, both direct and indirect (exclusive of Interest charges).		Net revenue due to works (not deducting Interest charges).			
				Direct receipts.				Enhanced share of land revenue or indirect receipts.		Total.				Including enhanced land revenue.		Excluding enhanced land revenue.	
	First crop.	First crop.	Second crop.	Public Works Department.		Revenue Department.		Estimate.	Actual.	Estimate.	Actual.	Estimate.	Actual.	Estimate.	Actual.	Estimate.	Actual.
				Estimate.	Actual.	Estimate.	Actual.					*See* statement B.					
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
	ACS.	ACS.	ACS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.
During 1889–90.	612,000	618,649	*53,590	73,250	1,14,912	18,50,769	†19,53,555	1,82,434	1,55,620	21,06,453	† 22,24,087	4,52,390	‡ 6,05,893	16,54,063	16,18,194	14,71,629	14,62,574

* No 'second-crop' area was included in the forecast statement.

† Exclusive of assumed 'old irrigation' revenue, Rs. 1,24,000.

‡ Exclusive of assumed old maintenance charges, Rs. 8,500.

GÓDÁVARI DELTA.

B.—Statement showing the estimate and actuals of Working expenses 1889–90 (*details of columns* 13 *and* 14 *of statement A*).

Year.	Estimate.			Actuals.												
				Direct charges.												
						Establishment.										
	Direct and indirect charges.*	Collection charges at 7·2 per cent. on revenue.	Total.	Extensions and improvements.	Maintenance and repairs.†	23 per cent. on expenditure.	10 per cent. on Public Works Department receipts.	6 per cent. on irrigation revenue.	Special establishment for Dowlaishweram Workshops.	Total.†	Tools and plant.	Refunds of revenue.	Total.†	Indirect charges.‡	Collection charges,§ Civil officers.	Total.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.
1889-90 ...	3,06,000	1,46,390	4,52,390	19,491	2,15,362	52,858	11,492	1,17,213	9,298	1,90,861	42,196	...	4,67,910	32,524	1,05,459	6,05,893

* The figures in column 2 give 8 annas per acre on the anticipated ultimate area of first crops (612,000 acres).

† Exclusive of Rs. 7,450 assumed cost of 'old maintenance charges' calculated at 6 per cent. on assumed 'old irrigation revenue' of Rs. 1,24,000

‡ Exclusive of Rs. 1,050 assumed '*old*' indirect charges.

§ Collection charges calculated at 7·2 per cent. up to 1883-84 and at 5 per cent. for subsequent years.

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The Government * Order on the above Report was as follows:—

"Ordered that a copy of the report by the Chief Engineer for Irrigation be sent to the Government of India with reference to its letter No. 5-I., dated 12th January 1891.

"2. In recording the completion of this magnificent project, which, while amply remunerative to the public exchequer, has conferred tenfold benefits on the people of the district, the Governor in Council cannot but claim for the works that, in conception and execution, they are such as any State might well be proud of."

The despatch from the Government of India forwarding the above Report and Proceedings of Madras Government, to the Secretary of State, and his despatch on the subject are printed below:—

"*Despatch from the Government of India, Public Works Department (Civil Works—Irrigation), to the Right Honourable Her Majesty's Secretary of State for India, dated Calcutta, 13th January* 1892, *No.* 2, *Public Works.*

"We have the honour to report that, in accordance with the rules contained in paragraph 155 of Public Works Department Code, volume II, chapter XV, section V, as modified by Standing Order No. 191 of 20th February 1890, the construction estimate of the Godávari Delta System of Irrigation and Navigation Works in the Madras Presidency has been closed with effect from the 31st March 1890, any subsequent outlay debitable to the Capital Account of the system being regulated by the rules in paragraph 156 of the same chapter of the code.

"2. The complete revised estimate for the Gódávari system, amounting to Rs. 1,30,32,653, was sanctioned in Lord Hartington's despatch No. 42 P.W., dated 17th August 1882. This sanction expired in August 1887, but was extended by us to the end of the financial year 1889-90. In August 1888 a redistribution of the sanctioned amount was authorised by the Government of India, which resulted in a reduction of Rs. 8,457 as shown in the margin, and the amount of the sanctioned estimate for the project now stands at Rs. 1,30,24,196.

	Secretary of State's sanction.	Redistribution sanctioned by the Govt. of India.
	RS.	RS.
Direct charges ...	1,10,88,695	1,10,89,332
Indirect charges ...	19,43,958	19,34,864
	1,30,32,653	1,30,24,196
Difference (reduction) ...	8,457	

"3. We invite your Lordship's attention to the attached report by the Chief Engineer for Irrigation, Madras, No. 60 I., dated 25th March 1891, which contains a brief history of the Godávari Delta System of Irrigation and Navigation Works.

"4. The total outlay, both direct and indirect, to end of 1889-90 stands at Rs. 1,27,19,245 as exhibited in the statement attached to the Madras Government Proceedings of the 7th October 1891, or Rs. 3,04,951 less than that of the revised sanction. Against this saving schedules of works which remained to be executed to complete the system after the closure of the construction estimate have been sanctioned by us, under the rules referred to in paragraph 1 of this despatch, to a total amount of Rs. 99,218.

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* Dated 23rd April 1891, No. 365-I., P.W.

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"5. The yearly revenue receipts from the system, as shown in columns 11 and 12 of statement A furnished by the Local Government, are better than the forecast submitted with the completion estimates; but the maintenance charges were under-estimated as explained in paragraphs 13 and 14 of the Chief Engineer's note, dated 25th March 1891. The net result is, however, a very close approximation to the figures given in the forecast. We may add that the share of enhanced land revenue credited to the system is likely to be increased considerably at the next settlement.

"6. The results achieved are extraordinarily good, and we consider that they reflect great credit on the officers who have been concerned in the inception and execution of this great system of irrigation. The annual surplus revenue after paying all charges, including interest on the capital outlay of Rs. 1,27,19,245, amounts to Rs. 11,86,318, which is equivalent to a return of 9·33 per cent. If interest charges be not included, the annual surplus amounts to Rs. 16,18,194, or 12·72 per cent. on the capital expenditure.

"7. These are the immediate financial results. The indirect benefits following on the creation of this large irrigated area cannot be similarly estimated in figures, but they are none the less substantial and enduring."

"*Despatch from the Right Honorable Her Majesty's Secretary of State for India, to His Excellency the Most Honorable the Governor-General of India in Council, dated India Office, London, 3rd March* 1892, *No.* 10, *Public Works.*

Financial results of the Godávari delta system of Irrigation and Navigation.

"I have received your Excellency's Public Works letter No. 2 of the 13th January 1892, reporting on the financial result of the Godávari delta system of Irrigation and Navigation works in the Madras Presidency, on the closing of the Capital Account on the 31st March 1890.

"2. I observe that on the above date the total outlay, both direct and indirect, amounted to Rs. 1,27,19,245, or Rs. 3,04,951 less than the revised estimate, and that you had sanctioned a further expenditure of Rs. 99,218 to complete the system.

"3. The annual surplus revenue after paying all charges, including interest on the capital outlay of Rs. 1,27,19,245, amounts to Rs. 11,86,318, which is equivalent to a return of 9·33 per cent.

"4. These results are highly satisfactory, and I cordially agree with you in considering that they reflect great credit on the officers who have been concerned in the inception and execution of this great system of irrigation."

How the sums Rs. 1,27,19,245 and Rs. 3,04,951 quoted in paragraph 4 of the Despatch of the Government of India, and paragraph 2 of the Secretary of State's Despatch, above printed, are arrived at, will be found in the following 'Statement':—

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Main and sub-heads.	Estimate sanctioned by the Secretary of State in his despatch No. 42, P.W., of 17th August 1882.	Redistribution of the estimate sanctioned by the Government of India in its letter No. 152 I., dated 15th Aug. 1888, printed with G.O., No. 511 I., dated 29th Aug. 1888.	Outlay to end of 1889-90.	Difference	
				As compared with the estimate sanctioned by the Secretary of State.	As compared with the revised estimate sanctioned by the Government of India.
1	2	3	4	5	6
DIRECT CHARGES.					
I. Works—	RS.	RS.	RS.	RS.	RS.
1. Head Works—					
B. Land	896	11,850	11,626	—10,730	224
C. Works	6,300	7,198	7,198	— 898	...
K. Buildings ...	45,393	48,189	48,187	— 2,794	2
O. Miscellaneous ...	...	5,304	5,304	— 5,304	...
Total ...	52,589	72,541	72,315	—19,726	226
2. Main Canals and Branches—					
B. Land	48,990	34,221	34,136	14,854	85
D. Regulators ...	42,794	43,718	43,720	— 926	— 2
E. Falls and weirs ...	5,580	5,580	5,580	...	...
F. River and hill torrent works.	48,834	50,452	50,453	— 1,619	— 1
F. (1). Other cross drainage works.	48,465	47,100	47,093	1,372	7
G. Bridges	29,978	27,764	27,764	2,214	...
H. Escapes	84,997	83,340	81,136	3,861	2,204
I. Navigation works.	10,67,579	10,39,692	10,40,736	26,843	— 1,044
K. Buildings ...	...	1,000	28	— 28	972
L. Earthwork ...	9,50,662	9,44,534	9,16,340	34,322	28,194
O. Miscellaneous ...	4,900	5,747	3,262	1,638	2,485
Total ...	23,32,779	22,83,148	22,50,248	82,531	32,900
3. Distributaries—					
B. Land	25,095	30,023	24,371	724	5,652
C. Works	3,06,169	3,31,695	3,16,098	— 9,929	15,597
L. Earthwork ...	1,92,917	2,23,549	2,05,680	— 12,763	17,869
O. Miscellaneous ...	1,172	1,097	1,097	75	...
Total ...	5,25,353	5,86,364	5,47,246	— 21,893	39,118
4. Drainage and Protective Works—					
B. Land	38,047	42,752	29,299	8,748	13,453
C. Works	1,20,309	1,24,562	1,25,893	— 5,584	— 1,331
L. Earthwork ...	6,63,493	6,68,310	6,61,293	2,200	7,017
Total ..	8,21,849	8,35,624	8,16,485	5,364	19,139
Provision for unforeseen works.	1,43,730	85,296	...	1,43,730	85,296
Total outlay on current sanctions.	38,76,300	38,62,973	36,86,294	1,90,006	1,76,679
Old outlay	42,99,072	42,99,072	42,99,072	...	...
Total, Works ...	81,75,372	81,62,045	79,85,366	1,90,006	1,76,679

Main and sub-heads.	Estimate sanctioned by the Secretary of State in his despatch No. 42, P.W., of 17th August 1882.	Redistribution of the estimate sanctioned by the Government of India in its letter No. 152 I., dated 15th Aug. 1888, printed with G.O., No. 511 I., dated 29th Aug. 1888.	Outlay to end of 1889–90.	Difference	
				As compared with the estimate sanctioned by the Secretary of State.	As compared with the revised estimate sanctioned by the Government of India.
1	2	3	4	5	6
DIRECT CHARGES—*cont.*	RS.	RS.	RS.	RS.	RS.
Brought forward ...	81,75,372	81,62,045	79,85,366	1,90,006	1,76,679
II. Establishment ...	20,11,645	19,97,796	19,55,654	55,991	42,142
III. Tools and Plant ...	9,01,678	9,24,513	8,88,198	13,480	36,315
III-A. Loss by Exchange.	...	4,978	5,512	— 5,512	— * 534
IV. Suspense Accounts ...	...	...	— 769	769	769
Grand Total ...	1,10,88,695	1,10,89,332	1,08,33,961	2,54,734	2,55,371
Less receipts on Capital Account.	...	...	899	— 899	— 899
Total, Direct Charges ...	1,10,88,695	1,10,89,332	1,08,33,062	2,55,633	2,56,270
INDIRECT CHARGES.					
Capitalization of abatement of land revenue.	15,36,364	15,36,364	14,93,582	42,782	42,782
Leave and pension allowances.	4,06,957	3,98,500	3,92,601	14,356	5,899
Total, Indirect Charges ...	19,43,321	19,34,864	18,86,183	57,138	48,681
Total, Direct and Indirect Charges, **Capital Account.**	1,30,32,016	1,30,24,196	1,27,19,245	3,12,771	3,04,951

The extra Rs. 99,218 of paragraph 4 of the Despatch of the Government of India and paragraph 2 of the Despatch of the Secretary of State "for works still to be carried out after the closure of the construction estimate" was in 1894 increased to Rs. 1,04,633,† against which there has been an expenditure including 'Establishment Charges' and 'Tools and Plant' of Rs. 1,02,586.

The total expenditure and charges under all heads against the *Capital* account of the system to end of 1893–94 amounted to Rs. *1,28,08,662* as shown in detail in Appendix No. I.

Besides this expenditure on *Capital* account, there has, to end of 1893–94, been spent and charged the *Revenue* account a sum of Rs. 2,95,69,867, as shown in the following statement :—

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* This amount has been adjusted by debit to Tools and Plant and credit to Loss by Exchange in the administrative accounts of 1890–91.

† P.M.G., No. 161 I., dated 20th February 1894.

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REVENUE ACCOUNT, GÓDÁVARI DELTA SYSTEM.

Statement showing the Expenditure and Charges to end of 1893–94.

		RS.	RS.	RS.
Extensions and Improvements	Works			4,61,808
Maintenance and Repairs	Works			73,49,083
Establishment Charges to end of 1881–82			23,17,567	
Establishment Charges, 1882–83 to 1893–94—				
23 per cent. on expenditure (exclusive of land compensation)		6,96,808		
10 per cent. on receipts in the P.W.D.		1,28,188		
6 do. on irrigation revenue		14,04,149		
Special Establishment for Dowlaishweram Workshop.		44,771		
			22,73,916	
				45,91,483
Tools and Plant				10,03,070
	Total, DIRECT CHARGES ...			1,34,05,444
INDIRECT CHARGES, VIZ.—				
Capitalized abatement of revenue on lands taken up for the works; and leave and pension allowances at 14 per cent. on establishment charges				8,75,790
Charges for collection of Revenue by Civil Officers. (This is a percentage charge on Irrigation Revenue; it has varied from time to time, is now calculated at 5 per cent.)				35,64,774
Interest on Capital Outlay calculated at 4 per cent. per annum on Direct Charges				1,17,23,859
	Total ...			2,95,69,867

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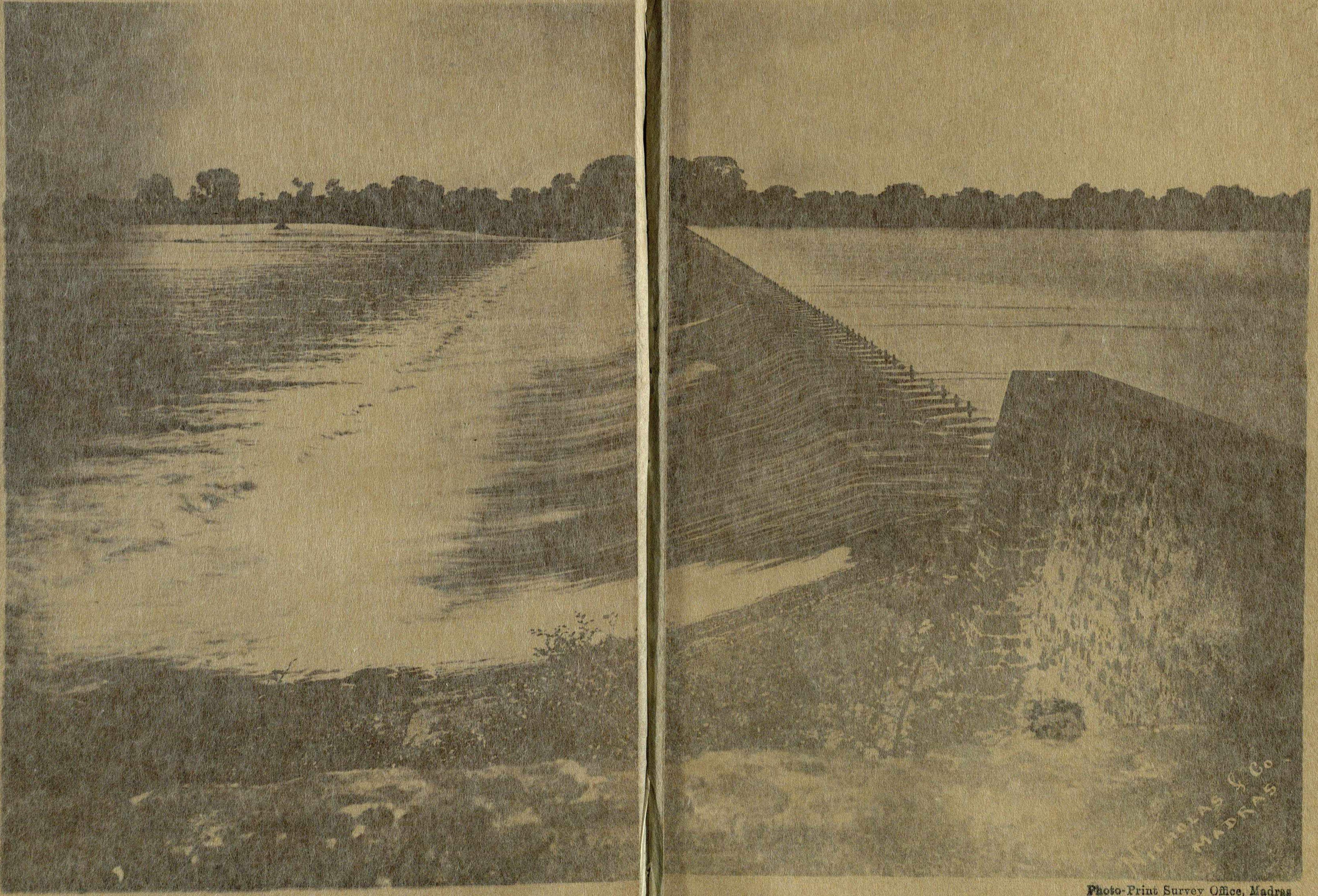

Photo-Print Survey Office, Madras
1895

MADDUR BRANCH OF AN ICUT—FROM EAST FLANK

(Water about 1- ·6 over Crest.)

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CHAPTER VIII.

GENERAL DESCRIPTION OF THE WHOLE SYSTEM OF CANALS, ETC.

THE History of the construction of the Works having been brought down to the present day, a brief description of their more important features as now existing will be given, which, with the Sketch Map at the end of Chapter I, and the three large scale maps of each Section of the Delta, at the end of volume II, will, it is hoped, give a clear idea of the whole system.

First then, commencing with the ANICUT AND HEAD WORKS: The Anicut has a total length of 11,945* feet of masonry, divided into four sections by intervening islands on which are embankments of an aggregate length of 7,365* feet; the tops of these embankments are 21 feet above the Anicut. The level of the crest of the masonry work is taken as + 38, the datum zero for it and for all the works of the system being approximately Mean sea-level. Along the top of the Anicut are cast-iron uprights with grooves down which planks are slipped when advisable, so as to temporarily raise the crest by 2 feet. The view facing this page, of the Maddúr branch of the Anicut with only a little water going over it, shows the tops of these posts.

As already stated, it is proposed to raise the whole length of the Anicut by 2 feet, in masonry.

The highest flood since the construction of the Anicut rose, on 3rd October 1891, to 17 feet above its crest, when, according to calculations, there was a discharge over the work of slightly more than † 1½ millions cubic feet per second.

The embankments between the sections of the Anicut are very important parts of the work, and it is well to note the necessity for most careful attention to their up-keep. Breaches through them would be far more serious than through the Anicut itself, because the enormous masses of stone in connection with the latter would fall into any gap and prevent rapid extension of the injury, whilst there would be no such automatic protection to arrest the spread of breaches in the embankments, and the rush of water through them would soon sweep away the thin crust of alluvial soil on the lankas and scour out the underlying sand to great depth, forming entirely new channels for the river, which would be most difficult and costly to close.

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* MASONRY.

	FEET.
Dowlaishweram Branch	4,940
Rallee Branch	2,859
Maddúr Branch	1,548
Vizéswaram Branch	2,598
Total, exclusive of Under Sluices and Wings ...	11,945

EMBANKMENTS.

	FEET.
Pichikalanka	2,300
Bobberlanka	1,385
Maddúrlanka	1,850
Chiggurulanka	1,830
Total ...	7,365

† P.M.G., No. 3112 R., dated 29th December 1892.

On the left flank of the Anicut adjoining the Dowlaishweram bank of the river are the Head Lock and Head Sluices of the Eastern Section of the Delta, and then the 'Under' or 'Scouring' Sluices, of 15 vents * from 5½ feet to 6 feet wide, the chief object of which is to prevent accumulation of sand, silt, and floating débris, in front of the Head Sluices—an object which is but imperfectly attained.

At a little more than half way across the river, at the western end of the Rallee branch of the Anicut, are the Bobberlanka Under Sluices also of 15 vents, from 5½ feet to 6 feet wide, and a little beyond them come the Central Delta Head Lock and Head Sluices.

On the extreme right flank of the Anicut, at the Vizéswaram bank of the river, is the third set of Under Sluices, of the same number and size of vents as the others, and then the Head Sluices of the Western Delta, close to which is the old Head Lock now converted into an extra Head Sluice (*see* Chapter V); a short distance up the river from the last-mentioned work stands the new Head Lock (*see* Chapter V), by which navigation passes to and from the Western Delta Canals, and by them to the Kistna System, and so to the Buckingham Canal (*see* Chapter XI).

Passing now from the Head Works to those in the three sections of the Delta and taking them in their usual order :

I.—EASTERN DELTA.

The water admitted through the Head * Sluices (originally of 13, but now 15, vents) passes into the MAIN CANAL. The appearance of the Canal at its head is shown in the photo-print, which faces this page, taken from the lower chamber of the Head Lock. The traffic through this lock is great, and the Canal here generally presents a busy scene, especially in the morning and evening when the numerous passenger or 'Rahadari' boats are arriving at or starting from the 'ghát' specially provided for them.

The 'theoretic' full supply of the Canal is 2,826 cubic feet per second, but since the cultivation in this section of the Delta has become greater than was expected, and two extra vents have been added to the Head Sluices (*see* Chapter V), a larger quantity of water is sometimes sent down the Canal; this is also the case with several of the Canals of the Delta, but the discharges stated in this Chapter will, unless otherwise stated, be those of the arrangements of the *revised* 'Completion Project' as shown in the 'Water-Distribution Statement' in Chapter VII.

At 65 chains from the head of the Main Canal, 1,344 cubic feet per second are taken off by the Bank Canal, the remaining 1,479 † cubic feet per second being carried on to 4 miles 12 chains where the main Canal bifurcates into the Samalkót Canal to the left and the Cocanada Canal to the right, 415½ cubic feet per second going to the former and 1,063½ cubic feet per second to the latter.

The first reach of the SAMALKÓT CANAL, 26¼ miles in length, skirts the high ground along the north side of the Delta, crossing the natural drainage

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* *See* plan in Atlas Volume.

† 3 cubic feet per second are used for *Direct* irrigation from the Main Canal.

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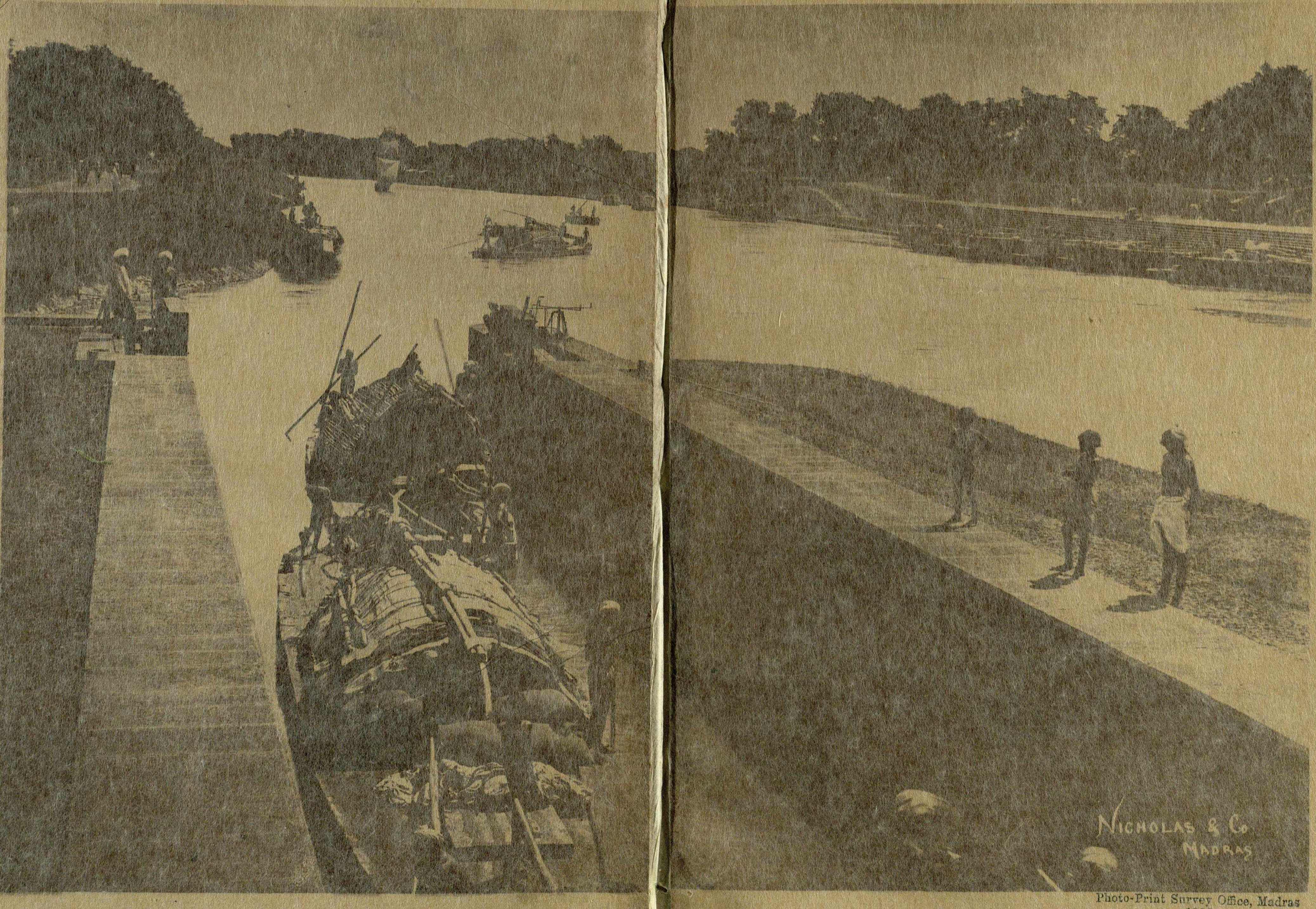

Photo-Print Survey Office, Madras
1895

HEAD OF MAIN C ANAL—EASTERN DELTA

(FROM LOWER C HAMBER OF HEAD LOCK.)

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of that part of the country; to provide for the minor drainages there are 43 'Inlets' into the Canal, and two Weirs which allow surplus water to pass out of it to the Biccavole (or *Bikkavol*) Drain, whilst the only large stream, the Yeléru, is taken under an Aqueduct of 5 spans, close to Samalkót.

At this point the Canal turns abruptly from a North-easterly to a South-easterly course and runs down the slope of the country for 7 miles to the outskirts of Cocanada. This slope necessitates the dropping of the water some 33 feet, which is arranged for by Weirs and Locks; the first Lock, a double one, of 16½ feet drop, is situated just beyond the Aqueduct abovementioned, at 30 miles 37 chains from the Head of the Delta; the second Lock is at 32 miles 68 chains, and the third is at 37 miles 9 chains, where the Canal ends at the navigable tidal creek into which empty the waters of the Yeléru and the Biccavole drain.

The irrigation under the canal is from its position confined almost entirely to the strip on its right side between it and the Biccavole drain; the area irrigated in 1893–94 was 28,625 acres of first crop and 2,915 of second crop.

There is not much through traffic along this canal, as it is not the most direct line to Cocanada, but the local traffic on it from the head of the Delta to Samulcotah and between that place and Cocanada is considerable. Samulcotah is a town of some 14,000 inhabitants, and an important station of the East Coast Railway.

The COCANADA CANAL runs nearly due east from the end of the Main Canal to Cocanada. Its total fall to tide water is of course the same as that of the Samalkót Canal, but the slope of the country along which it runs being fairly uniform, its Locks (4) and their Weirs are more evenly distributed along its whole length than in the case of the Samalkót Canal; their positions are 9 miles 38 chains, 15 miles 73 chains, 20 miles 41 chains and 29 miles 4 chains, **D.M.*, the last being a tidal lock.

As stated in Chapters I and IX, parts of this Canal occupy the original course of the Tuliabaga drain and are therefore somewhat tortuous and uneven.

The Canal proper ends at, and locks into, an artificially improved navigable tidal creek, which after a course of about 2 miles joins the creek from the end of the Samalkót Canal, abovementioned, and the two form the 'Cocanada River,' where all the landing and shipping of the port is carried on.

The full supply of the Canal at its head is 1,063½ cubic feet per second, but 482 cubic feet of this go off to the Mandapet Canal at 6 miles 45 chains, (*D.M*)., the remainder being used to irrigate some 46,000 acres (46,658 in 1893–94) which lie on both sides of the Cocanada Canal, northwards to the Biccavole drain, and southwards to the Tuliabaga drain.

At about 1¼ mile above the end of the Cocanada Canal is the head of the Kovúr-Manjair Canal.

The traffic along the Cocanada Canal is very large; in 1894–95 there passed through its terminal lock at Kovúr 8,834 boats going upwards, which carried 6,207 tons of goods and 56,402 passengers; and 9,007 boats going downwards, which carried 73,318 tons of goods and 40,575 passengers.

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* *D.M.* = *Delta Mileage*, measured from head of delta.

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The BANK CANAL, which leaves the Main Canal at 65 chains from its head, runs for 32 miles along the left bank of the Gautami Gódávari; it then turns away from it and after a further course of nearly 8 miles, locks into the Coringa River about half way between Coringa and Yanam. It takes, from the Main Canal as its full supply, 1,344 cubic feet per second, 737 cubic feet of which it parts with to the Coringa Canal at 13 miles 3 chains (*D.M.*), the remainder being used for the irrigation of some 25,000 acres (24,917 in 1893–94) which lie chiefly on the left side of the Canal between it and the Téki drain.

Much of the land commanded by this Canal is better suited for 'dry' than for 'wet' crops. This fact was not fully recognized when the original 'Completion Project' was prepared, and the forecast then made was 40,399 acres; this, however, was reduced to 20,000 acres when the Project was revised. The Canal is a useful line of communication for a considerable tract of country, and has five locks, of the second class.

The CORINGA CANAL, which leaves the Bank Canal in its 13th mile, runs in a generally easterly direction for 22 miles 24 chains to a navigable tidal creek, into which it locks, near Coringa. Of the 737 cubic feet per second which enter this Canal, as a full supply, 253 cubic feet go off to the Injeram Canal at 21 miles 69 chains (*D.M.*), the remainder being used in irrigating 33,099 acres (in 1893–94) lying north and south of the Canal between it and the Tuliabaga and Téki drains and the Injeram Canal.

At 24 miles (*D.M.*), the Mundapetta Canal joins the Coringa Canal on its left bank. There are three Locks (second class) on this Canal; just above its terminal, 'tidal' one, the Kovúr-Manjair Canal comes in from the Cocanada Canal.

The INJERAM CANAL, which leaves the Coringa Canal at 21 miles 69 chains (*D.M.*), runs to the South-east for 11 miles 9 chains and ends at the Téki drain, but is *not* locked into it. It irrigates 15,439 acres (in 1893–94), chiefly on its right bank, as far as the Téki drain. Being a 'blind' canal, with no tidal lock at its end, the traffic along it is small. It has one lock of the old design with revetted sides to its chamber.

The MUNDAPETTA (or *Mandapet*) CANAL, which leaves the Cocanada Canal at 6 miles 45 chains (*D.M.*), runs in a South-easterly direction for 13 miles 35 chains when it joins the Coringa Canal, as already stated. It passes through a rich piece of country and, throwing out distributaries on both sides for its whole length, it irrigates 31,867 acres (in 1893–94), an area greater in proportion to its length than any other Canal in the Eastern Section of the Delta, or indeed than any Canal in the *whole* system, excepting the Undi Canal in the Western Delta.

It has two Locks (of the second class) and serves a considerable amount of traffic passing between the Head of the Delta and the Coringa Canal.

Besides the seven Canals above noticed which were made primarily for Irrigation, but have also been suited for Navigation in the Eastern Section of the Delta, there is in it another Canal which was undertaken primarily for *Navigation* though it is used to some extent for irrigation; this is the KOVÚR-MANJAIR CANAL. It runs from the Cocanada Canal at 1¼ mile above its tidal Lock to the Coringa Canal a short distance above its tidal Lock, and its length is a little over 9 miles. It was originally proposed in order to facilitate the carriage of salt from some large 'pans' or factories

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which lie along its course, and therefore a portion of its cost was borne by Imperial Funds, but the remainder was, in consideration of its convenience for general traffic, borne by Local Funds. Its total cost was Rs. 1,79,401 * exclusive of the cost of its irrigation sluices and distributaries, some of these being required to supply lands previously supplied direct from the Cocanada Canal.

The following list gives in a tabulated form some of the information about the Canals above dealt with, and in the Atlas Volume will be found 'Condensed Sections' of them :—

List of Canals classed under Main Head (2) MAIN CANALS AND BRANCHES—EASTERN SECTION OF THE DELTA.

Distance of Head of Canal from Head of Delta.		Names of Canals.	Lengths of Canals.		Remarks.	Areas irrigated in 1893–94.	
						1st crop.	2nd crop.
MILES.	CHAINS.		MILES.	CHAINS.		ACRES.	ACRES.
...	...	MAIN	4	12	......	622	...
...	65	BANK	39	78	Head on Main Canal.	24,917	2,895
13	3	CORINGA	22	24	Head on Bank Canal.	33,099	2,540
21	69	INJERAM	11	9	Head on Coringa Canal.	15,439	2,633
4	12	COCANADA ...	27	28	To Robertson's Creek Bridge	46,658	6,843
28	...	KOVÚR-MANJAIR...	9	11	Head on Cocanada Canal		
6	45	MANDAPET ...	13	35	Do. do. ...	31,867	7,642
4	12	SAMALKÓT ...	32	77	To Cocanada Lock ...	28,625	2,915
		TOTAL ...	160	34	All navigable... ...	181,227	25,468

The DRAINAGE OF THE EASTERN DELTA is provided for by three main drains, natural in parts but greatly enlarged and improved, known as the *Biccarole* or '*Bikkavol*,' the *Tuliabaga*, and the *Téki*, to each of which there are numerous affluents.

The 'BIKKAVOL' DRAIN serves the 75 square miles or so lying between the Samalkót and Cocanada Canals, and also takes the large quantity of drainage from the uplands which crosses the Samalkót Canal in its first 25 miles. The drain joins the Yeléru, which passes under the Samalkót Canal by the Aqueduct near the end of its first reach, and the two united flow into the tidal creek below the Cocanada tidal lock at the end of the Samalkót Canal.

The 'TULIABAGA' DRAIN now begins at the Surplus Weir from the Cocanada Canal at 7 miles 23 chains (*D.M.*) and after a course of about 25 miles, falls into a tidal creek. It serves the piece of country, some 140 square miles, lying between the Cocanada, Mandapet and Coringa Canals. Near its end it passes under an Aqueduct of 16 arches of 12 feet span, which carries the Kovúr-Manjair Canal.

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* This is not included in cost of the Gódávari Delta System, shown in Appendix No. I.

The Téki Drain begins at the Surplus Weir at the head of the Coringa Canal, and after a course of upwards of 27 miles joins the Coringa River near the end of the Bank Canal. It serves in all some 180 square miles of the country between the Coringa, Injeram, and Bank Canals, and that between the Mandapet, Bank, and Coringa Canals, the drainage of the latter tract being brought to it by the Nallúr and Kalér affluents which pass under Aqueducts carrying the Coringa Canal over them.

River Embankment.

The whole length of the Gautami Gódávari in this Section of the Delta, from the Anicut to Yanam, is embanked, so as effectually to exclude all river floods.

II.—Central Delta.

The Bobberlanka Under Sluices and the Head Lock* and Head * Sluices of the Central Delta lie at the end of a long leading channel from the river, and the accumulation of silt and sand in front of the two head works is a serious trouble which the Under Sluices, as is the case with so many such works, do not prevent. It has been suggested that the construction of another set of Under Sluices on the other (right) side of the Head Sluices and close to them, may meet the difficulty, but their success in securing the desired end is problematical, whilst they would certainly add a new danger to the Navigation using the Head Lock, which is already troubled by the 'drag' to both the Under Sluices and Head Sluices.

The water admitted through the Head Sluices 15 vents of 6′ × 10′ (*see* Chapter V and Plan in Atlas Volume) passes into the Main Canal which is for some distance from the head in very deep sand cutting. The theoretic full supply is 1,745 cubic feet per second, and this is carried for 8 miles 4 chains to where the canal bifurcates into the Bank Canal to the left, and the Gunnaram Canal to the right.

The Bank Canal runs as a Navigable Canal for 39 miles close to the right bank of the Gautami Gódávari and of the Vriddha Gautami branch. It takes as its theoretic full supply 423 cubic feet of water per second and irrigates some 35,000 acres (34,998 in 1893–94). It has a Lock at its head and three other Locks at 20 miles, 27 miles, and 38 miles 51 chains (*D.M.*) respectively. It is from a short distance above the last Lock, at Annampalli, that the water will have to be taken off for the Polavaram Island (*see* Chapter I) when its Irrigation is carried out. The matter is thus referred to in Colonel Hasted's report with the *revised* 'Completion Estimates.'

"The site of this (Annampalli) Lock has been fixed with reference to the possibility of the Polavaram Island being at some future time irrigated by water taken across the Vriddha Gódávari by means of an Aqueduct or a bank. It is, of course, desirable that if an Aqueduct is required the water to be carried should be at as high a level as possible, but there seems to be some probability of this small branch silting up altogether. Whatever may happen the lock is placed so far down that water can be taken across when necessary under favourable circumstances."

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* *See* plans in Atlas Volume.

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The Bank Canal is not connected at its end with tide water and the traffic along it is small. At 22 miles (*D.M.*) there is a navigation cut 4 miles long, known as the 'Billakurru Canal,' to the Amalápuram Canal.

The GUNNARAM CANAL starts at the end of the Main Canal with a theoretic full supply of 1,307 cubic feet per second, but this it carries for only 36 chains, when it sends off 626 cubic feet to the Amalápuram Canal. For the whole of its navigable course of 37 miles, the Gunnaram Canal keeps close to the bank of the Vasishta Gódávari, crossing its 'Vainatéyam' branch near its head by the Gunnaram Aqueduct (*see* Chapter VI).

This Canal, like all others in the Gódávari and Kistna Deltas which run close to the rivers, is a source of great trouble on account of the dangers to which it is subjected by the 'sets,' and encroachments of the river.

The temptation to take Canals close along the edges of the rivers has been irresistible, because from such a position it is easy to command the considerable strip of exceptionally rich land which always slopes away from the margins of deltaic rivers to the first inland drainage, and also because part of the earth from the excavation of the canals can be used in making the river embankments along them. The cost of such Canals, therefore, at first appears small, but in the long run they are generally exceptionally costly, because of the extensive and expensive protection which has to be resorted to in places to prevent their being washed away by river encroachments, and because of the costly diversions, through very valuable lands, which have to be made when such protection proves of no avail. The danger from river encroachment on a '*Bank*' Canal is not infrequently increased by percolation and leakage from itself; these hasten on the caving in of the river margin by washing out at the face of its scarp the thin layers of nearly pure sand so generally found interspersed with the firmer deposits for some distance back from the edges of deltaic rivers.

The area irrigated by the Gunnaram Canal in 1893–94 was 40,514 acres of first crop; of this more than two-thirds lie in the Naggaram Island where the soil generally is of the richest description and exceedingly fertile when it receives a sufficiency of moisture. This was not the case till the construction of the Gunnaram Aqueduct rendered it possible to bring the Anicut water across the intervening branch of the river. When that was accomplished, and the Gunnaram Canal and its channels had distributed water over the face of the Island, it speedily became the 'Garden of the Gódávari.' For besides its thirty odd thousand acres of rice crop, it grows thousands of acres of other, and even more valuable, crops, which would not be raised were it not for the Anicut system, though no return from them is credited to it. For instance, many of the channels are lined for miles by extensive plantations of Cocoanut trees which pay no water-tax though they undoubtedly owe their luxuriance, and to a great extent their very existence, to the effect of the channels alongside which they have been planted. And this is also the case in several other parts of the Delta.

The Canal has five Locks in all, and its through navigation is provided for by the lowest of these connecting it with tide water in the Visishta Gódávari, at Sakinétipalli, about 3½ miles above Narsapur.

The AMALÁPURAM CANAL leaves the Gunnaram Canal just below the head of the latter. It runs through the very heart of the true △ of the Gódávari, past the large town from which it takes its name, and ends, after a course of

31½ miles as a navigable canal, at about 2 or 3 miles from the sea. Its full supply is 626 cubic feet per second (of which 179 are for the Bendamúr-lanka canal) and its irrigated area is nearly 31,000 acres (30,835 in 1893-94).

In its upper reaches it passes through Cocoanut plantations and garden cultivation of the finest description, which derive great benefit from it even when ostensibly they do not take its water; in its lower reaches it enters on a country of poorer soil, but well suited for rice. Its navigation is provided for by four Locks, but it is not connected with tide water.

The Billakúrru navigation cut from the Bank Canal joins this Canal at 25½ miles (*D.M.*), and at 30 miles (*D.M.*) there strikes off to the right, the BENDAMÚR-LANKA CANAL which skirts the town of Amalápuram on its west side, and is navigable for 2½ miles to the Indapalli Weir. It was originally intended to continue this as a navigable canal along the bank of the Vainatéyam branch of the river to Bendamúr-lanka, but, as stated in Chapter VII, this intention was abandoned on account of extensive encroachments of the river. The area irrigated by the Canal was in 1893-94 acres 10,692.

The following List gives in a tabulated form some of the information about the Canals in this Section of the Delta, and in the Atlas Volume will be found, 'Condensed Sections' of them :—

List of Canals classed under Main Head (2) MAIN CANALS AND BRANCHES—CENTRAL SECTION OF THE DELTA.

Distance of Head of Canal from Head of Delta.		Names of Canals.	Length of Canals.		Remarks.	Areas irrigated in 1893-94.	
						1st crop.	2nd crop.
MILES.	CHAINS.		MILES.	CHAINS.		ACRES.	ACRES.
...	...	MAIN	8	4	...	23	627
8	4	BANK	38	73	Head at end of Main Canal. Navigable for 35 miles 4 chains only ...	34,998	2,007
22	...	BILLAKURRU	4	...	Head on Bank Canal		
8	4	GUNNARAM ...	37	76	Do. at end of Main Canal.	40,514	4,355
8	40	AMALÁPURAM ...	31	40	Head on Gunnaram Canal.	30,835	2,511
30	...	BENDAMÚR-LANKA	8	20	Head on Amalápuram Canal. Navigable for 2 miles 24 chains only.	10,692	39
		TOTALS ...	128	53	Only 118 miles 68 chains navigable.	117,062	9,539

The chief Drainage lines of this section of the Delta are—

First—The Gorinkala Drain: running east of and roughly parallel to the Gunnaram Canal from about 14 miles (*D.M.*) and emptying into the Vainatéyam Gódávari about 6 miles below its head.

Second—The Upper Kowsika Drain: which also lies between the Gunnaram and Amalápuram Canals and is joined to the Gorinkala just above its outfall, by the 'Sakarru Cut.'

Third—The Lower Kowsika Drain: between the lower reaches of the Amalápuram Canal and the Bendamúr-lanka Canal and its main distributaries; this drain falls into the '*Panchinadi Drain*,' an artificial cut with its outfall into the Vainatéyam Gódávari near its mouth.

Fourth—The Kunavaram Drain: an almost entirely artificial channel running East from near the left side of the Amalápurm Canal at 37 miles (*D.M.*) to a salt-creek near the sea. Into this drain fall several minor drainages between the Bank and Amalápuram Canals.

Besides the Drainages abovementioned, there are several minor ones which have independent exits to the river or tide water.

River Embankments.

The whole length of the branches of the Gódávari which enclose and run through this Section of the Delta are fully embanked, except for short distances near their mouths.

III.—Western Delta.

The Head Sluice of the Western Delta has 15 vents 5½′ to 6′ wide and 7½′ high, and within the last few years the old Lock of 15′ wide has been converted into an extra sluice of two vents. The *theoretic* full supply of the section is 3,945 cubic feet per second, or more than five times the ordinary summer discharge of the Thames at Staines. Since the area to be irrigated has increased beyond what was anticipated, considerably more than the theoretic quantity above named is at times taken in from the river, and the Main Canal is then a stream carrying about two-thirds of the maximum *flood* discharge of the Thames.

This large quantity of water passes into the Main Canal, the length of which is 6 miles measured along its most direct, navigation, channel, but part of the water is conveyed by two tortuous old channels which leave the direct canal at 1 mile and 2⅜ miles respectively. They unite and rejoin the direct line at 4 miles, from whence for another 2 miles, to Chettipett, the old course of the Rallu Madugu is followed, and that stream, draining some 280 square miles of country, is taken into the artificial system of Canals, an arrangement which is a frequent source of trouble and danger. Surplus water thus at times brought into the Canals is intended to be passed out of it by two powerful Weirs, one at Chettipett with 100 feet clear length of crest at 4 feet below canal F.S.L., and another at Nandamúr, 2 miles further on along the Ellore Canal, with 45 feet clear length of crest at 3 feet below F.S.L. The water sent over these weirs passes to the Weyéru, but even with their great discharging capacity, some 3,500 cubic feet per second, they cannot always sufficiently relieve the Canals. Sometimes the Head Sluices have to be entirely closed and no water taken in from the river for days together.

At 6 miles the Main Canal bifurcates into the Ellore Canal which continues westward at as high a level as possible, and the Kákaraparru Canal which turns sharp off to the left, down the Delta.

The KÁKARAPARRU CANAL : is 10⅜ miles long, for the greater part of which it is entirely in cutting. It starts with the large theoretic full supply of 1,650 cubic feet per second, but irrigates only some 10,000 acres, its chief function being to carry the water required to the Góstanadi and Velpúr, the Bank Canal, and the Narsapur Canal. It has no locks, and its slope and velocity are somewhat greater than is convenient for 'up' navigation.

The GÓSTANADI AND VELPÚR CANAL : takes as its full supply 487½ cubic feet per second out of the Kákaraparru Canal over a Weir in the right bank of that Canal at 1 mile 35 chains from its head. Close to the weir is the Góstanadi and Velpúr Head Lock. For the first 14 miles the Canal is simply the old Góstanadi drain improved so as to be navigable, the water being held up by a Weir from just above which, near the village of Velpúr, the purely artificial Canal of that name begins. All surplus water which enters the Góstanadi above this Weir passes over it to the stream below, which is left solely to its legitimate use as a drainage. From this point the Canal runs S.W. for rather more than 20 miles, past the town of Bhimavaram to where it drops by a lock into the tidal portion of the Yanamaduru drain, about 10 miles above its outfall into the Upputéru.

There are on this line of navigation two Locks (second class) besides the *Head* and *Tidal* Locks, already mentioned.

Its area of irrigation is upwards of 40,000 acres.

The next branch from the Kákaraparru Canal is the BANK CANAL; it starts at 14 miles 68 chains (*D.M.*) and runs close to the river for nearly 26 miles; it then locks into the tidal creek into which the Nakkala Drain empties, just where it joins the Gódávari, about 10 miles above Narsapur and nearly opposite the Sakanétipalli tidal Lock at the end of the Gunnaram Canal, Central Delta.

Like the other 'Bank' Canals this one is a source of frequent anxiety and expense owing to encroachments of the river.

The Canal for the greater part of its course runs through very rich soil, and though from its position the land it commands lies only along its western side, it irrigates no less than 35,000 acres.

It has three Locks (second class) including the tidal one; the first is upwards of 10 miles from its head, so that there is an unbroken reach of 25 miles from the Head of the Delta; experience has shown that it would have been well to have had a lock much nearer the head of the Canal.

There are two 'Surplus Weirs' in the first 2 miles of the Canal, the water from which passes into the Nakkala Drain.

The NARSAPUR CANAL states from the end of the Kákaraparru Canal, with a theoretic full supply of 765 cubic feet a second, and has a course of almost 30 miles to where it locks into tide water of the Upputéru, near Mogalturu. It is a very important Canal as regards both Irrigation and Navigation. The area of wet cultivation under it is upwards of 67,000 acres, considerably greater than that under any other Canal in the whole Gódávari

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system. It runs past many important towns and markets, the principal of which are Pálakollu and Narsapur where in days of yore there were flourishing 'Factories,' the former belonging to the Dutch, and the latter to the East India Company. At Narsapur there is a tidal Lock into the estuary of the Vasishta Gódávari, by which traffic can pass between the Central and Western Deltas *viâ* the Sakanétipalli Lock at the end of the Gunnaram Canal. By the tidal *Lock* near Mogulturru traffic can pass to and from the Upputéru and by it to and from the Kistna System, which locks at two places into the Upputéru. There are, besides the two tidal Locks just mentioned, five Locks (first class) on this Canal.

The ELLORE CANAL is taken from the end of the Main Canal along the upper edge of the Delta, for a distance of 40 miles 32 chains, to near the large town of Ellore, where the *Kistna*-Ellore Canal locks down into it. Its theoretic full supply is 683½ * cubic feet per second, and it irrigates some 58,000 acres, a considerable portion of this being by two large distributaries known as the 'Mid Level' and 'Low Level' Channels, which have their Head Sluices in the Junction Canal, and run roughly parallel to the Ellore Canal at about 1½ and 2½ miles distant from it.

The large amount of traffic between the Gódávari and Kistna districts and also that to and from Madras and the South, passes along this Canal, which, with the Main Canal, forms a navigable reach of nearly 46½ miles, in the Gódávari System, without a lock.

The Canal runs right across the water-shed of some 1,295 square miles; the drainage from 850 square miles of this is passed under the Canal at 8 miles (*D.M.*) by the Nundamúr Aqueduct of four arches of 40 feet span over the 'Yerra-kalva'; the remaining 445 square miles and some of the spill of the Yerra-kalva in high floods are provided for by 10 'Under-tunnels' or small Aqueducts; 18 'Inlets'; 8 'Outlets' (with crests at about F.S.L.) of an aggregate length 1,087 feet; and 4 'Escapes.' Full information will be found in P.M.G. Nos. 401 I., dated 21st June 1880, and 314 I., dated 1st April 1882, about these cross-drainage works. They have proved efficient, but the Canal is sometimes damaged by influx of spill water from the Tammiléru which ought to cross the *Kistna*-Ellore Canal.

As the Canal now under consideration has a 'dead end' at the Ellore Lock where the Canal from the Kistna joins it at a higher level, there is often trouble from the accumulation of silt there. The demands on the Canal for irrigation along its whole length also make it difficult to always keep it in as perfect a state for its great traffic as is desirable; this will be found noticed in the 'Memorandum' printed with the special Chapter (No. XI) on 'Navigation.'

The ATTILI CANAL takes off from the Ellore Canal a short distance below its head, its theoretic full supply being 475½ cubic feet per second. It has a navigable course of 15 miles 74 chains, with two Locks (second class), to the town and important market from which it takes its name. Its distributaries are extensive, and its irrigated area was in 1893–94 no less than 31,884 acres.

The JUNCTION CANAL, length 3 miles 25 chains, from the Ellore Canal at 13 miles (*D.M.*) to the Venkiah, was constructed solely in the interests of

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* Exclusive of what it carries to the Attili Canal.

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navigation, but as it cut through the ‘Mid Level’ and ‘Low Level’ channels, their heads are now in it. It has, near its lower end, a double Lock (first class) with a total drop of 13 feet, plan of which will be found in the Atlas Volume.

The VENKIAH AND * WEYÉRU.—Length from end of the Junction Canal to the Upputéru near Yelurpád is 32 miles 63 chains. For some 22 miles the course followed is chiefly that of the Weyéru which used to convey most of the Yerra-kalva to the Colair Lake (*see* Chapter I), and that portion is by no means a satisfactory line for navigation, being tortuous and of very uneven section. At 21 miles 17 chains (*D.M.*) there is a double Lock, and at the end of the Canal 45 miles 18 chains (*D.M.*) a tidal Lock into the Upputéru, by which and two tidal Locks at the end of Kistna Canals, there is through communication with that system.

From 35 miles 35 chains (*D.M.*) near Chinnakápáram there is a channel, partly artificial, known as the ‘Old Weyéru,’ with an old fashioned lock † at its head, by which before the Ellore Canal was carried out, a considerable amount of traffic used to go to the Colair Lake and so to near Ellore; a route of course now disused. Near the Chinnakápáram Lock are two Weirs by which 2,250 cubic feet per second of flood water can be surplussed to the Colair Lake.

The water for the ‘Venkiah and Weyéru, and for its branch, the Undi Canal, 513 cubic feet per second for the former and 612 cubic feet for the latter, is passed over the Chettipett Weir, at the end of the Main Canal, into a natural tortuous channel which joins the Yerra-kalva, or Weyéru, just above the Nundamúr Aqueduct, Ellore Canal, and flows under that work. Near that Aqueduct used to be the Lock from the Ellore Canal into the Weyéru, but for 6 miles or so the course of that stream was so tortuous and ill-suited for navigation that the Junction Canal, just above described, was constructed to avoid it.

The area irrigated by the Venkiah and Weyéru in 1893–94 was 44,538 acres, and there is a possibility of considerable extension, as the swamps along the Upputéru and the Colair Lake become raised and drained.

The UNDI CANAL: leaves the Venkiah and Weyéru at 19 miles 74 chains (*D.M.*) and has a length of 20 miles 23 chains; of this, however, only 15 miles 67 chains are navigable, as far as the important town and market from which the Canal takes its name.

The water for the Canal is admitted by two sluices, the theoretical full supply being 612 cubic feet per second, and in 1893–94 it irrigated 52,858 acres, an area greater in proportion to its length than any other Canal in the Gódávari System; there is also a possibility of further extension, as the low-lying lands towards the Upputéru become more fitted for cultivation.

There is only one Lock (of the second class), besides the Head Lock on this Canal.

The following List gives in a tabulated form some of the information about the Canals in this portion of the Delta, and ‘Condensed Sections’ of them will be found in the Atlas Volume:—

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* The lower 10 miles used to be known as the Akid Canal.

† *See* plan in Atlas Volume.

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List of Canals classed under main head (2) MAIN CANALS AND BRANCHES—WESTERN SECTION OF THE DELTA.

Distance of Head of Canal from Head of Delta.		Name of Canals.	Length of Canals.		Remarks.	Areas irrigated in 1893-94.	
						1st crop.	2nd crop.
MILES.	CHAINS.		MILES.	CHAINS.		ACRES.	ACRES.
...	...	MAIN	6	...	... ..	1,194	80
6	...	KÁKARAPARRU ...	10	30	Head on Main Canal.	9,413	3,805
7	35	GÓSTANADI AND VELPÚR.	34	12	Head on Kákaraparru Canal.	42,567	4,669
14	68	BANK	25	43	Do. do.	35,068	12,412
16	30	NARSAPUR ...	29	68	Head at end of Kákaraparru Canal.	67,036	9,613
6	...	ELLORE	40	32	Head at end of Main Canal.	57,897	3,828
9	55	JUNCTION	3	25	Head on Ellore Canal.		
6	70	ATTILI	15	74	Do. do.	31,884	9,073
13	...	VENKIAH AND WEYÉRU.	32	63	Head at end of Junction Canal.	44,538	1,247
35	35	OLD WEYÉRU ...	5	35	Head on Weyéru at Chinakápavaram Lock; imperfectly navigable.	...	...
19	74	UNDI	20	23	Head on Venkiah Canal; navigable for 15 miles 67 chains only.	52,858	1,262
		TOTAL ...	224	5	Only 214 miles 14 chains navigable (exclusive of 'Old Weyéru').	342,455	45,989

The following are the chief DRAINAGE lines of the Western Delta, all of them having, of course, many affluents :—

First—The NAKKALA DRAIN;—commencing from the head of the Bank Canal, runs between it and the Narsapur Canal, for about 28 miles to the Gódávari at about 10 miles above Narsapur. It has a large sluice at its outfall to prevent the river floods from backing up it and swamping the adjacent lands; and over this sluice a distributary of the Bank Canal is carried. In the early days of the Gódávari works the Nakkala was utilized for navigation by having water thrown into it, and a Lock built near its head. This has now been removed and the drain restored to its legitimate duty.

Second—The KAZA DRAIN; starts from near the left bank of the Narsapur Canal at about 27 miles (*D.M.*), and after a course of 16½ miles falls into the Gódávari about 2 miles above Narsapur. It also has an outfall sluice to exclude river floods and high tides.

Third— The MOGALTURRU DRAIN.—This serves the strip of country on the west side of the Narsapur Canal between it and one of its large distributaries, the Jinnur Channel. It falls into a tidal creek near the mouth of the Upputéru.

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Fourth—The Gontéru Drain; commences to the west of the head of the Narsapur Canal and after a course of some 30 miles joins the Mogalturru Drain near its outfall.

Fifth—The Góstanadi.—This was (*see* Chapter I) originally one of the channels by which part of the flood waters of the Rallu-Madugu, as well as the drainage along its own valley, used to find its way to the sea. Its upper 14 miles, as already described when dealing with the 'Góstanadi and Velpúr Canal,' have been made navigable, but the rest of it is exclusively a drainage stream and carries off the surplus water from the country between the Velpúr and Attili Canals. It joins the Yanamaduru Drain about 4 miles above Bhímavaram.

Sixth—The Yanamaduru Drain, which takes its name from a village near its end, is really an old branch of the Weyéru enlarged, when that river was canalized, to take most of its flood waters southwards to the Upputéru instead of westwards to the Colair Lake. In order to retain the water at a height suitable for navigation in the Venkiah and Weyéru, and also to allow surplus water to flow down the Yanamaduru, there is at its head, near the village of Duvva, a Weir with 300 feet length of crest. The upper 2 feet, or so, of this is formed of planks intended to be removed when floods come down the Yerra-kalva, but when these are sudden it is not always possible to get the planks out, and too much water is forced down the Venkiah doing considerable damage. An arrangement which will secure the possibility of manipulation of the shutters under all circumstances is a much-needed improvement.

It is probable that before very long the floods of the Yerrakalwa may be rendered less violent by the construction of a large storage reservoir on its upper waters for the irrigation of some 45,000 acres. The scheme, known as the 'Unnamalanka Project' was worked out in 1874 by Lieutenant (now Colonel) A. R. F. Dorward, R.E., who afterwards carried out many of the 'Completion' works in the Gódávari Western Delta.

Seventh—The Bondada Drain; takes the drainage of a considerable portion of the country between the Undi Canal and the Venkiah and Weyéru and passes it under the Aqueduct which carries the former Canal where it ceases to be navigable. The Drain then runs due south for about 9 miles and falls into the Yanamaduru, where tidal.

Eighth—The Pandikodu, of which '*Beckley's Drain,*' and the '*Bodapad Drain*' are large affluents, takes to the Colair Lake the drainage from between the upper portion of the Venkiah and Weyéru and the Ellore Canal for some 10 miles west of the Junction Canal, and also the upland waters which cross the Ellore Canal in that portion of its course. West of this again the upland drainage and that south of the Canal are conveyed to the Colair Lake by several separate drains.

River embankments.

The Vasishta Gódávari which forms the Eastern boundary of this section of the Delta is thoroughly embanked to Narsapur, below which the river floods do not raise the water level of the estuary much above High water, Spring-tides.

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CHAPTER IX.

VARIOUS INFORMATION AS TO MATERIALS, DESIGN, ETC., OF WORKS.

EARTHWORK—CANALS AND CHANNELS.

DESIRE for cheapness of construction and for showing results as soon as possible, led to an extensive use of old native channels and natural water-courses, for conveying the Anicut water to various parts of the Delta. For instance, in the Eastern Section the 'Tuliabaga,' partly an old artificial Channel, but for most of its length the natural main drainage of that part of the country, (*see* Chapters I and VIII) was converted into what are now known as the '*Main*' and '*Cocanada*' Canals which are therefore in parts tortuous and unsightly; and an entirely new and costly drain has had to be dug to take the place of the one diverted to other purposes. So also in the Western Section, the 'Weyéru' was canalized (*see* Chapter VIII), providing but an indifferent line for Navigation and necessitating the excavation at great cost of a new Channel, known as the *Yanamuduru*, to take the flood waters of the Yerra-kalva in a different direction to the sea; and when the '*Completion*' Project was carried out, it was found advisable to construct a '*Junction Canal*' from the Ellore Canal to the 'Venkiah and Weyéru' at about 6 miles from the original head of the latter near Nundamúr, so as to avoid that length of its most tortuous navigation.

Nothing can be more certain than the inadvisability of attempting in a delta country to use the natural drainages for other than their legitimate purposes.

The adoption of old native irrigation channels for the purpose of distribution, though at first apparently an economical course, has also in the long run proved anything but satisfactory, as, of course, they were faulty in alignment, gradient, section, and every conceivable particular. On this subject, so long ago as 1853, Colonel Baird Smith remarked: *

"In looking at the channels of the Godavery Delta irrigation, that exceeding irregularity of alignment, which was noticed in the case of the corresponding works on the Kistnah, inevitably arrests the attention. It was further forced on my notice on my personal inspection of parts of some of the principal channels; and the views I have formerly expressed regarding this most objectionable feature in the works apply here with equal force. Economical considerations have doubtless led to the adoption of these old and tortuous lines, but I have no doubt as to what the final result will be. Just as in these North-West Provinces we are now abandoning, one after the other, the old alignments and straggling channels which our predecessors bequeathed to us, so, as water increases in value, and more land is brought under profitable occupation, will the present system on the Godavery Delta be given up, and perhaps wonder expressed that one so wasteful should ever have been adopted even as a temporary expedient. The home and local authorities have just sanctioned an expenditure of upwards of 1½ lakhs of rupees, or £15,000, on the construction of 25 miles of

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* Baird Smith's "Irrigation in the Madras Provinces."

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new channel for the Eastern Jumna Canal, expressly to get rid of those twists and low levels which the adoption of an old line entailed, and which have for years past led to great waste of water, heavy annual repairs, and, after all, great inefficiency of the works. The old line will now be abandoned, the whole of its works broken up, and a tract of the canal, on which not less than 2 lakhs of rupees, or £20,000, have been expended in original works, will cease to exist to the entire satisfaction of every one concerned, whether on the part of Government or of the agricultural community. Far greater expenditure is contemplated in the rectification of the false alignments and levels of the Western Jumna Canal; and, as I said before, what experience had led us to do now might, with far better effect, be done at once, without any intermediate period, in the works of the Madras Presidency. The projected channels are generally unexceptionable in the particulars under review, and my remarks apply with effect to those in which the water is already flowing, and only to some among these." . . . .

The discharging capacity given to the various Canals and its relation to the areas intended to be irrigated will be found in the 'Abstract Water-Distribution Statement' given in Chapter VII. In designing the Canals and distributaries the formula used up to 1879 was that known as '*Du Buat's*,' but since that date the more accurate formula and coefficients of *Bazin* have been adopted, viz., $V = c.\sqrt{r.s.}$ in which

V = velocity in feet per second.
$r.$ = Hydraulic 'radius,' or 'hydraulic mean depth,' in feet.
$s.$ = Fall in unity, of surface.
$c.$ = A variable coefficient which for earthen channels is arrived at from the formula.

$$C = \frac{1}{\sqrt{0{\cdot}00008534\left(\dfrac{r + 4{\cdot}1}{r}\right)}}$$

The *Side slopes* generally adopted for earthwork in the Delta have been $1\frac{1}{2}$ (*base*) to 1 (*height*).

MASONRY—AND MASONRY WORKS.

Brickwork has been little used in the Delta except for arches; almost all the works are constructed of *Concrete* and *Rubble Masonry* with, in the more important works, *Ashlar* facings, quoins, and copings.

CONCRETE.—The foundations are, as a rule, platforms of concrete of various thicknesses according to the nature of the sub-soil and the weight of the superincumbent work. The concrete isgenerally composed of 3 parts, by measurement, of *stone* broken to 2 inches gauge, and 1 part of *mortar;* laid and rammed in layers of about 6 inches thick; the mortar used in this was usually of 1 part slaked lime, 2 parts river sand, and from $\frac{1}{2}$ to 1 part of finely ground brick dust, known in India as '*surki*'; the concrete so made was excellent. It may be of use to here give an extract from a record of some experiments made in 1887 at Dowlaishweram about '*Surki*' mortar. . . .

"1 lime, $\frac{1}{2}$ *surki*, 1 sand make (with the lime procurable at Dowlaishweram) the best mixture when it has to be placed in water *at once*, but both 1 lime, 1 surki, 1 sand; and 1 lime, 1 surki, 2 sand, make good mixtures, with little to choose between them, except that the latter is the cheaper. When a few hours can be allowed *before* submersion, 1 lime, $\frac{1}{2}$ surki and 2 sand, excellent."

It was customary for a long time to cover concrete foundation platforms with 'rubble' masonry, to form the floors of locks, sluices, &c., but it was

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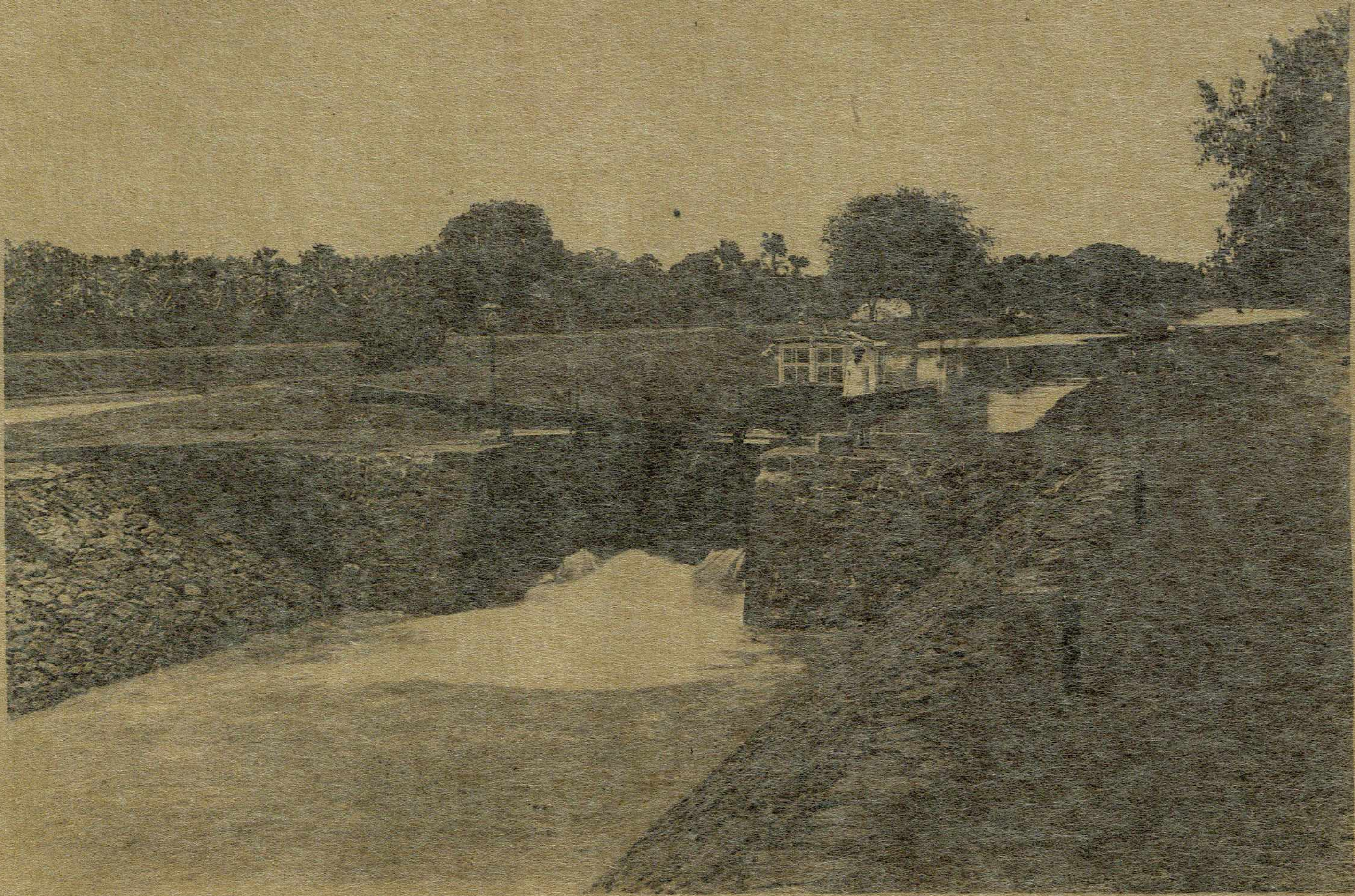

Photo.-Print Survey Office, Madras, 1896

MUKKAMALA LOCK (OLD STYLE).
CHAMBER BEING FILLED THROUGH VALVES IN UPPER GATES.

afterwards found better not to put the layer of rubble, but to bring up the concrete to form the floors.

The stone used is a sandstone, generally from quarries near Dowlaishweram, but in some cases in the Western Delta, obtained from quarries lying above the Ellore Canal.

Locks.—When the works were first started and economy was of the greatest importance, most of the Canal locks were of the general design, which will be found in the plan of the 'Chinakapavaram Lock' in the Atlas Volume.

They had only just so much masonry as was necessary in connection with the sills and the gates, the chambers between them being formed merely by earthen slopes revetted with stone. (*See* view of Mukkamala Lock, facing this page, from a photograph by W. J. Howley, Esq., Assistant Engineer.)

When cheapness of first cost and rapidity of construction are necessary in a country where skilled labour is difficult to obtain, such locks are excellent. They have however the drawback of requiring considerably longer time to 'change' (fill and empty) than locks of an equal capacity for traffic which have vertical, or nearly vertical, chamber walls; and when traffic developes to any considerable extent, the time occupied in lockages becomes important. The consequence is that with three or four exceptions the old 'Earthen' Locks have been replaced by masonry ones, in most of which, built under the 'Completion Project,' the arrangements are such that they can be filled or emptied in three minutes by means of 'side culverts,' the valves being worked by rack and pinion gearing.

Two of the new second-class locks in the Central Delta, at Gopalapuram * and Annampalli, were built entirely of Concrete, except their sills and gate quoins, but it was not found that there was any advantage in this style of construction, whilst it is decidedly inferior in appearance to that with walls of rubble masonry faced with small ashlar, locally known as 'dressed faces.'

The Lock Gates are of the usual vertical two-leaf style, actuated by lever beams, except in one case in which the upper gate is of the horizontal 'tumble'† type adapted from an American ‡ pattern. Its working, owing probably to small errors in design, has not proved entirely satisfactory.

There are in the Gódávari Delta two sizes of Locks, viz., 'First' and 'Second' class. The chamber of the former is 150′ × 20′, that of the latter 105′ × 15′. The following are the Canals which have first-class Locks :—

Eastern Delta.—'Main' and 'Cocanada Canals.' *Western Delta.*—'Main,' 'Narsapur,' 'Ellore,' 'Junction,' and Venkiah and Weyéru § Canals.

Including the Head Locks, there are in the whole system, 16 Locks of the first class and 41 of the second class.

Plans of two head locks, of three first-class, and four second-class Canal Locks, and of two of the old Locks, will be found in the Atlas Volume.

Weirs.—In the Gódávari System nearly every Canal Lock has its *Weir*, over which the water for irrigation is passed on to the reach below; there are

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* *See* plan of Gopalapuram Lock in Atlas Volume.

† *See* plan in Atlas Volume.

‡ For description *see* 'Notes on Navigable Rivers and Canals of the United States and Canada.'—WALCH.

§ The Perimella Double Lock, an old one, is only 15 feet broad, but the Yelúrpad Tidal Lock at end of Canal is 20 feet.

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46 of them, and there are also 27* 'Surplus Weirs,' to relieve the Canals of any excess of water which may enter them from drainage or otherwise.

These works have, as a rule, been designed with a length capable of discharging the maximum required, with a depth of from 2½ feet to 3 feet going over the crest, on which are wooden shutters of that height, lifted or lowered at will by screw-gearing. Nine feet has been found a convenient length for such shutters.

The form of Weir adopted has wisely been that with a vertical overfall. In the first works of the kind, the fall was on to a horizontal floor of large stone, but in subsequent works a 'water cushion' was generally introduced, its floor being still made of large stone, covering 'rubble' masonry. Even then it was found that not infrequently the massive flooring stones were blown up, doubtless by the impact of the falling water acting on air spaces in their joints and beddings, due to irregularity of shape, and imperfect workmanship. Concrete was then resorted to for the floors, and it has proved not only cheaper but better in every way than stone, never, if well laid, requiring more than slight repairs to the surface.

In the construction of the 'water cushions,' the cushion walls were at first made nearly vertical; it was found however that stones and gravel carried into cisterns so formed, were not readily ejected, but remained grinding about on the floor. To remedy this, the up-stream faces of the cushion walls were given a gentler and gentler slope, till at last the greater part of the floor itself was taken into the reverse slope and no abrupt line was left in it (*see* plan of Bellampudi Surplus Weir in Atlas Volume). This has proved perfectly efficient.

The superiority of a vertical overfall for weirs in such positions is shown by the little trouble the Gódávari Canal Weirs have given compared with that which resulted on the 'Ganges Canal' from the adoption of the 'Ogee' form, with reference to which Mr. Buckley in his excellent book '*Irrigation Works in India*,' says: "These 'Ogee' falls have given endless trouble. The velocity increased of course as the water ran down the 'Ogee' and the friction on the slope was enormous; the shock on the floor was reduced, but the friction did as much damage as the shock would have caused, and the velocity was so great that a standing wave was created below the fall, and the washing of the banks was considerable."

Plans of six Lock Weirs and two Surplus Weirs will be found in the Atlas Volume.

Aqueducts.—The largest Aqueduct in the System is that over the Vainatéyam branch of the river, to which Chapter VI has been devoted. There are no others so large as to merit special description, but as a good instance of one of the recent smaller Aqueducts, a plan of one in the '20th mile of the Ellore Canal' is given in the Atlas Volume.

Irrigation Sluices.—Of sluices at the head of Irrigation Distributaries there are some 500 in the Gódávari Delta System. Those built in the old days bear evidence of the indifferent workmanship then only obtainable, and also of a desire to cheapen them by scrimping the masonry; they were fitted with 'paddle' or 'needle' shutters worked by hand. Few of them now remain; some have been altered, but most have been replaced by much

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* Exclusive of the eight 'Outlets' on the Ellore Canal.

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improved structures fitted with shutters, worked by screw-gearing, which admit of careful regulation. All the more recent sluices are widened out from close behind the shutter so as to lessen the velocity of the water as it issues into the channel and so obviate the necessity for much protection to its bed and banks immediately below the work.

Bridges.—There is probably no artificial Irrigation and Navigation system, except perhaps the neighbouring one of the Kistna, in which the provision of Bridges per mile of Canal and Channel, is so small as in the Gódávari Delta. This has arisen from the fact that when the works were commenced, and for long after, there was not a single made road in the Delta, and the people were accustomed to wade through the streams and water-courses which crossed their pathways, or when the water was too deep for wading, to use 'dug-outs,' or rafts supported on hollowed-out palmyra trunks, locally known as '*Sungadies.*'* Instead of Bridges, therefore, such '*Sungadies*' and at more important crossings, *ferry-boats* (locally known as '*balla-kats*'†), which can carry carts and cattle, have been provided; some 250 of these sungadies and ballakats are maintained by Government on the Canals and larger artificial drains.

Bridges have however been provided over the tail-bays of almost all the Locks, and of late years a few have been constructed at other places on the large Canals, at the expense, or partly so, of Local Road Funds.' These bridges are iron-girder structures, with tow-paths under them along the faces of the abutments, and at the corners of the abutments vertical revolving rollers; before the introduction of these rollers both masonry and tow-ropes used to be much worn away.

The following are the rules for Headway, &c., for Bridges over the Navigable Canals:—

"*First-Class Lines of Navigation.*

"*First*—If there be more than one arch, the arches to be not less than 30 feet span, or 25 feet exclusive of a 5 feet tow-path. If there be but one arch, 40 feet to be minimum span.

"*Second*—The clear headway under the arch or arches should give a rectangle 12 feet wide and not less than 11 feet above full supply or ordinary flood level.

"*Third*—The waterway of canal should not be contracted so as to produce a velocity in excess of 1·5 feet a second.

"*Second-Class Lines of Navigation.*

"*First*—If there be more than one arch, the arches to be not less than 27½ feet span, or 23 feet exclusive of a 4½ feet tow-path. For a single arch bridge, 30 feet to be the minimum span.

"*Second*—The clear headway under the arch or arches should give a rectangle 10 feet wide and not less than 9½ feet high above full supply or ordinary flood level.

"*Third*—The waterway of canal should not be contracted so as to produce a velocity of more than 1·5 feet a second."

As for the smaller Irrigation Channels, they are rarely provided with any artificial means of crossing; they have to be waded across. This, however, it must be remembered, is no great inconvenience in a warm climate where shoes and stockings are not worn and the usual lower single garment, which seldom extends below the knee, is easily lifted.

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* Telugu *San* = together, *katte* = tie or fasten.

† Do. *Balla* = plank, *katte* = tie or fasten.

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CHAPTER X.

IRRIGATION.

IRRIGATION is the primary object of the Gódávari Anicut and Delta works, and to it the present prosperity of the once poverty-stricken district is chiefly due; for, though the effect of the *Navigation* so successfully combined with it, has been by no means small, *Irrigation* is the principal factor in the grand results which have been obtained. It enables valuable crops to be grown with certainty year by year over 1,000 square miles, where without it there would be but a comparatively small area of uncertain cultivation, and it thereby not only prevents the famines which used to ravage the district, but provides a large surplus of food-grains for export to less favoured regions. And whilst conferring these inestimable blessings on the people, it replenishes the Public Exchequer by *direct* returns which yield from 10 to 14 per cent. on the capital expended, and by *indirect* returns which, though impossible to estimate in figures, are truly characterized by the Government of India as "substantial and enduring."

It is not possible to arrive with certainty at the area which it was originally expected would be irrigated, and naturally there was a good deal of vagueness on the subject. In his 'Second Report' (*see* Chapter II) Sir Arthur Cotton took the area of cultivable land commanded in the 'Rajahmundry district' to be 816,000 acres, and apparently assumed that the whole of it would be cultivated with irrigated crops. Towards the end of the same report however we find him saying, "We may consider the Annicut as first; *Laying* * *the foundation* of the complete irrigation, for a rice crop, of the whole delta of the Godavery, and part of that of the Kistna, in all 3,000 square miles, or nearly 2,000,000 acres." It is difficult to believe that he meant that this enormous area would be irrigated from the Gódávari, but the Board of Revenue doubtless so understood him, for in its letter sending on his report to Government, it said, "Major Cotton estimates the extent of land that may be efficiently cultivated with sugar-cane by means of the Annicut at 100,000 acres, which would be adequately supplied with water throughout the year. The entire remainder of the Delta, and of the land to its left and right (including what is available in the Masulipatam district), it is believed may be cultivated with paddy, which requires a regular supply of water for only about four months. The area of this tract in Rajamundry is estimated to be 820,000 acres and as much more in Masulipatam."

The Board itself however seems to have had an idea that such anticipation was extravagant, and further on in its letter remarked, "The Collector's accounts of the area of the Delta differ considerably from the estimate (derived from the map) of Major Cotton. . . . It is however sufficient for the purposes of this report to assume as true the lowest estimate of the culturable lands, namely 616,000 acres, which, if brought under the influence of the Annicut, would immeasurably repay the cost of all the works." How close to the actual results was this smaller anticipation of the Board will be seen further on.

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* Not italicized in original.

Much of the differences of opinion amongst local officers as to areas, arose from the fact that there was not then, nor for many years after, any cadastral survey or Revenue Settlement of the district.*

The growth of irrigation, which immediately followed the construction of the Anicut was doubtless rapid, but there is no means now of ascertaining particulars about it. In 1869 however Captain J. G. Ryves, R.E., then Superintending Engineer, gave the irrigated area thus—

	ACRES.
Eastern Delta	147,000
Central do.	81,000
Western do.	208,000
Total ..	436,000

This was considerably more than returned by the Revenue officers, but may probably be taken as approximately correct. When the first "completion estimates for the Eastern and Western Sections of the Delta" were sent in (1871), the 'ultimate area' of first crop for the whole Delta was taken as 579,470 acres, but as the improvement works progressed, the increase in irrigation more than kept pace with them, and by the time the 'revised estimates' were submitted (1882), the actual irrigation had come up to 588,066 acres. The new forecast with those estimates and the one for the Central Delta was 612,000 acres, thus disposed—

	ACRES.
Eastern Delta	170,000
Central do.	122,420
Western do.	319,580
Total ..	612,000

In seven years more even this had been exceeded by 6,000 acres, and four years later still (1893–94), the actual irrigated area had grown to 640,744 acres of first crop and 80,966 acres of second crop, as shown in the 'Abstract Water-Distribution Statement' with Chapter VII.

It will be thus seen that, since the 'completion works' were undertaken, twenty-four years ago, the irrigation has gone on increasing till it is now half as much again as it then was, and the question naturally suggests itself, will the increase continue to any considerable extent? It is not possible to give a positive answer to this question, but some consideration may be given to the two main points which affect it, viz., (first) the area still available for extension of irrigation, and (second) the sufficiency of water.

As regards the first of these, the following is extracted from Colonel Mullins' Note of 14th March 1882 on the revised 'completion estimates':—

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* Were carried out between 1858 and 1860.

	SQUARE MILES.	ACRES.
"Gross area of the Delta exclusive of Polaram Island ..	1,980	1,267,200

Sections.	Gross area.		Area commanded.
	Square miles.	Acres.	Acres.
1	2	3	4
Eastern	445	284,800	188,293
Central	505	323,200	165,800
Western	1,030	659,200	417,531
	1,980	1,267,200	771,624

"The areas entered in column 4 are taken from Mr. Wilson's memoranda, and are said to have been furnished by the Revenue authorities. It seems probable that they refer to the area commanded and considered suitable to irrigation, to the exclusion of roads, channels, drains, village-sites, swamps, &c., for the gross area commanded must manifestly be a larger proportion of the gross area of the delta."

It may therefore be assumed that there is land available for an extension of irrigation of at least 100,000 acres, exclusive of the considerable areas in the Coringa and Polavaram Islands, to both of which Anicut water could be taken without any very serious Engineering difficulty; to the former by a tunnel, or by articulated pipes, under the Coringa river, and to the latter by an Aqueduct across the head of the 'Vriddha Gautami' (*see* Chapter VIII).

But when we come to deal with the question of the sufficiency of water for any considerable increase of irrigation, the answer is not so simple. In 1869, Captain J. G. Ryves, when considering the subject, wrote thus:—

"9. The monsoon rice crop is raised during the six months—June to November. In an ordinary year the river begins to rise about the middle of June; during July, August and September it discharges, per unit of time, from 20 to 120 (in great floods 150) times, as much as would be required for 600,000 acres. During October and November it falls gradually, till, at the end of the latter month, the supply in front of the Annicut does not exceed one and-a-half, or even in a bad year one million cubic yards per hour. The supply during November is, however, sufficient in even bad seasons to mature 600,000 acres of paddy. The crop is reaped early in December.

"10. But in a very bad year, when the south-west monsoon rainfall has been below the average and the north-east monsoon has altogether failed, the supply during November would be insufficient to bring to maturity a rice crop of 600,000 acres. Such a season might occur once in 12 or 15 years, and would bring with it loss of part of the crop."

And in 1892 the then Chief Engineer for Irrigation made the following remarks in his Inspection Notes, printed with P.M.G. 34, I., dated 11th January 1892:—

"When the so-called 'completion estimates' were prepared, the expected ultimate area of irrigation was 579,470 acres. As the works were carried out, it became evident that this area might be exceeded, and when the revised estimates were prepared in 1882, the ultimate expected area was increased to 612,000 acres (first crop). Year by year the area actually irrigated, has gone on increasing till, last year (1890–91), it was 613,137 acres of first crop. That area cannot be considerably exceeded without a certainty that in some years it will be impossible to fully supply all the land, and there will be disappointment and loss to cultivators."

Though, as Captain Ryves states in the extract above given, there is for three months or so in every year vastly more water coming down the river than would suffice for every acre commanded, the excess passes over the Anicut and runs uselessly to the sea, whilst in almost every irrigation season the period of superabundance of water is followed by one of scanty supply which barely suffices, under existing arrangements, to bring to maturity the whole of the present area of wet crops. There are only two means by which this difficulty in the way of considerable extension of irrigation can be met—; one, the increase in the 'DUTY'* of the water, and the other, the STORAGE of some of the surplus which now runs to waste, using it to supplement the river discharge when low.

In considering the former of these means, it must be remembered that, as there is not in the Gódávari system any control over the smaller village and field channels, and large areas are irrigated merely by flow from field to field, it is not possible to enforce strict economy in the use of water. That *something*, however, has been already accomplished in that direction, by improved sluices and distribution arrangements, is shown by the fact that whereas the duty of water for rice cultivation used to be taken as only 66 acres per cubic foot per second, it was found by the time the revised 'completion' estimates were submitted, that a duty of 81 acres might be adopted for the Western Delta, in which lies more than half the irrigation of the whole system; and a 'Statement' with the Administration Report for 1893-94 shows the actual duty for the whole first crop irrigation of the Gódávari Delta in that year to have been rather over 88 acres. Doubtless too much trust must not be placed in the accuracy of such a 'Statement' which is compiled from somewhat insufficient data, but at all events it seems certain that the old allowance of 1 cubic foot of water per second for each 66 acres of rice has been proved to be considerably in excess of what is absolutely necessary over large areas of delta lands; and recent observations by Mr. Chatterton † in the Kistna district point to the probability of a duty of 90 acres being not too high to expect. But even so, the quantity of water brought down the Gódávari at certain periods of the irrigation season is not in all years sufficient for any considerable extension of the present area of wet cultivation.

It would appear therefore that, to secure such extension without occasional and not infrequent "disappointment and loss to cultivators," *Storage* must be resorted to. That there are sites on some of the large affluents of the Gódávari where such storage can be effected at a cost not prohibitory, seems highly probable, though no investigations have yet proved this to be the case.

In the above remarks it will be noticed that the cultivation of rice is taken as governing the consideration of the case. This is because nearly nine-tenths of the lands irrigated from the Anicut grow rice, and rice only. Unlike most of the crops grown under the canals of the North-Western Provinces and the Panjâb, which require only periodical waterings, rice requires continuous flooding for almost the whole period of its growth. That period varies from about three and-a-half to six months, according to the description of the rice grown, the better kinds requiring the longer time for coming to maturity.

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* The 'duty' of water is the area which a given quantity of it will efficiently irrigate. It is usual to take 1 cubic foot of water per second as the unit of quantity.

† *See* Circular Memorandum of Chief Engineer for Irrigation, No. 32-G, dated 28th July 1894.

But, though rice is the staple growth of the irrigated part of the delta, the other crops which take water are of no mean area or value; the former was returned in 1893-94 as 84,572 acres, and the latter, at a very low valuation, as Rs. 18,51,946. They are mostly 'Garden Crops' which consist chiefly of Sugar-cane, Betel-vine, Plantains, Chillies, Onions, and Garlic. As they are generally more valuable crops than rice and remain longer on the ground, they pay double its water-rate.

The rules and rates connected with Irrigation, which have obtained since 1873 with slight modifications from time to time, are given below:—

Rules for levying Water-rate in the Kistna and Godavery Deltas.

RULE I.

"The water-rates charged for irrigation in the Godavery and Kistna Deltas are as follow:—

"(1) For a single *wet* crop, Rs. 4 an acre.

"(2) For a second *wet* crop on irrigated land, Rs. 4 an acre, provided that the cultivator may compound for irrigation for two crops for a term of years not less than five, for Rs. 6-8-0 an acre.

"*N.B.*—A second crop is a crop grown on land on which a first crop has been grown in the same fasli.

"(3) For a second *dry* crop on irrigated land, Rs. 2 an acre, except where the land-holder has compounded under Clause 2.

"(4) For sugar-cane, betel, plantains, and other garden-produce, remaining on the ground for the time of two crops, Rs. 8 an acre, provided that the cultivator may compound for a term of years not less than five, for Rs. 6-8-0 an acre.

"*Note.*—Cocoanuts and other trees forming tope plantations will be charged the same rates as the garden crops above referred to, if they take water for a number of months in the year sufficient for raising two crops. If not, they will be charged the rate for a single wet crop.

"(5) For a dry crop grown on land for which irrigation has never been supplied, or, having been once supplied, has been since discontinued under Rule III, Rs. 2 an acre, whether the crop be a first or a second crop.

"(6) When the water used for irrigation cannot be obtained without raising it by baling or mechanical contrivances, a deduction of one-fourth of the water-rate will be made.

"(7) When the Collector considers the supply of water to be precarious, the charge for a single wet crop will be Rs. 2 an acre.

RULE II.

"(1) Cultivators will be allowed to take or to refuse irrigation for *wet* crops every year, on condition that a formal application, specifying the number and extent of the fields for which irrigation is sought or declined, be made to the head of the village, and, after registry by the Curnam, be sent to the Tahsildar up to the following dates:—

"Applications for irrigation to be supplied—

"(*a*) For a first crop, 31st March.
"(*b*) For a second crop, 30th November.
"Applications for irrigation to be discontinued, 31st March.

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"(2) When water is required for *dry* crops under Rule I, Clause V, the application may be made at any time.

"(3) When water is not available for all applicants, applications will ordinarily be admitted in the following order :—

"(*a*) To applicants for water for two crops, or one of sugar-cane, etc.

"(*b*) To those who have received water longest, preference being given to those whose lands lie nearest the head of the channels.

"(4) In the case of all applications for irrigation to be supplied, water being available, and of all applications for irrigation to be discontinued, the Tahsildar will admit the application, endorse it to that effect, and give it back to the Curnam for delivery to the applicant.

"(5) Printed forms of these applications will be kept in stock by the Curnam.

"(6) A register of applications, showing whether they have been admitted or rejected, will be kept both by the Tahsildar and the Curnam.

"(7) The Tahsildar will send extracts from his register to the Executive Engineer of the division concerned every week. The Curnam's register will be kept open to inspection by the villagers.

RULE III.

"When land has once been irrigated as *wet* land, it will be described as such in the accounts, and will be supplied with water, and remain liable to the water-rate (water being available) until a formal application for the irrigation to be discontinued has been made and admitted in the manner prescribed in Rule II.

RULE IV.

"Application for water for *dry* crops grown on *dry* land, *i.e.*, land for which irrigation has never been supplied, or, having been once supplied, has been since discontinued under Rule III, may be made at any time to the Curnam, who will send one copy to the Delta Gumastah or Overseer, and one to the Tahsildar.

RULE V.

"When water is taken for land not previously irrigated, or of which the irrigation has been relinquished, or when it is taken for raising a second crop, wet or dry, on a registered single crop wet land, before a formal application for water has been made by the ryot concerned and accepted by the Tahsildar as prescribed in Rules II and IV, or after an application has been refused, a water-rate equal to twice the rate chargeable according to Rule I will be exacted. Double water-rate will also be charged if water be taken from a sluice or channel or other source of supply other than that which is provided or approved by the responsible officer of the Public Works Department. The Collector may, for sufficient cause, remit or reduce the penal portion of the water-rate.

RULE VI.

"(Cancelled—Board's Proceedings, No. 219, dated 4th April 1891.)

RULE VII.

"No water-rate will be levied for a single crop on lands in Inams and Zemindaris which have been determined by the Collector under the orders of the Board of Revenue to be entitled to irrigation from before the time the anicut was built as 'mamool wet' lands.

RULE VIII.

"Water will be granted free of charge on application to the Department Public Works officers, through the Collector, for flooding lands made barren by

'Soudoo,'* whenever a sufficient supply of water is available, for a period not exceeding two years, provided that, if a crop or crops are raised on the land during this period, half the usual water-rate will be charged.

RULE IX.

"Anything in the foregoing rules notwithstanding, Government reserve to themselves the full right, with or without reason given, to discontinue either temporarily or permanently the supply of water for irrigation."

Whilst this work was being prepared for the press, orders have been issued that, from the 1st July 1895, the rates above given shall be raised 25 per cent. all round.

The aggregate length of Irrigation Distributaries in the whole Gódávari Delta System is nearly 2,000 miles.

The average rainfall in the Delta during the Irrigation season of June to December, is between 40 and 50 inches.

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* A salt efflorescence.

CHAPTER XI.

NAVIGATION.

The advisability of attempting to make canals serve the double purpose of Irrigation and Navigation is a subject round which from time to time there has raged much discussion. On the one side the chief advocates for the combination have been Sir Arthur Cotton and those who followed him on the delta works; on the other side have been ranged those who argued from theory, and many Engineers who, in the parts of India with which they were acquainted, had seen the attempted combination prove a costly failure, as on the Ganges Canal. On both sides there has been a tendency to too great generalization, and to a want of appreciation of the effect of local conditions; for instance, in a recent excellent work on 'Irrigation Works in India,' it is stated that "As a matter of fact, it cannot be said that the combination of navigation with irrigation has been successful in India; the traffic has always proved * to be far less than the projectors of the works anticipated" . . . . . How incorrect this is as regards the Gódávari system will be seen further on.

In connection with the Gódávari works the question of combining Navigation and Irrigation soon came to the front. Even when sending in his first general estimate, with his 'Second Report' Major Cotton h[illegible] (*see* page 22), that one of the results to be expected from the works [illegible] he contemplated, would be that "a complete system of internal navigation intersecting the whole delta would be established throughout the year." And besides the 'Head Locks,' the estimate included a provision of one lakh for "Sluices, *Locks*, and other small masonry works." The smallness of this provision, which could not have been intended for more than half-a-dozen † or so of even the small and inexpensive Locks [illegible]ally proposed, shows that there was but a very imperfect [illegible] on the part of Major Cotton himself of what would be requ[illegible] to make the main irrigation arteries of the system into really efficient lines of communication also. It is not therefore to be wondered at that, when the detailed estimates for the various canals came in with large sums set down for Locks and special arrangements for Navigation, the Government should have regarded the provisions for that purpose as almost a new development of the original intentions to which sanction had been given.

The Governor of the day, Sir Henry Pottinger, even went so far as to say with reference to recommendations which had been made for certain Navigation works, "I ‡ cannot shut my eyes to the fact, that this is an entirely novel scheme which, so far as I recollect had no existence in the original project for an Annicut across the Godavery"; whilst in the resulting

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* It is added further on "The Canals in which navigation has been most successfully combined with irrigation are the Gódávari system in Madras and the Orissa and Midnapore systems in Bengal."

† In his letter No. 184, dated 3rd August 1849, *Captain Orr* gives the number required as *10;* there are *now* 54 (exclusive of Head Locks).

‡ His minute, dated 1st January 1853.

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orders of Government * it is asserted "that contrary to what was originally contemplated when the project of the Annicut was proposed and sanctioned, the system of Navigation is *now treated to a great degree as the paramount object.*"

But Colonel Cotton was determined that his chief Canals should be made navigable. In a 'Memorandum,' dated 23rd February 1853, we find him writing thus :—

"The necessity for channels does not depend upon a great increase of exports, though that would render them much more valuable and important, nor even upon an export trade at all. The district must have communications for its internal traffic, whether it exports or not. A million of people cannot exist without interchange of commodities. And it is very much cheaper to make the irrigation channels navigable than to make roads; besides, that the former will convey goods at a twentieth part of the rates by the latter. Second: The question seems to me rather to be what data are there to conclude that the export trade, which has increased in ten years from three lacs to 14 lacs, should on a sudden become stationary, and that too when the quantity of a produce is increasing, and the cost of produce decreasing every year, in consequence of the new works. The market for rice, tobacco, sugar, and oil-seeds, is in fact, in comparison of the extent of this delta, almost unlimited; and the quantity that will be taken from it depends upon one main thing, the cost of its production: if Rajahmundry can grow these things cheaper than it did, it may export a hundred times what it does now. The new works will certainly reduce the cost of produce, on an average, one-half; and (of course always excepting extraordinary contingencies) nothing can stop the present increase of the export trade, unless we absolutely prevent the produce being conveyed to the coast by the want of communications. I am info [illegible] there is again a great increase of the export trade this year.

"I really am totally at a loss to say anything new on this subject: what I have here said has, in substance, been repeatedly submitted in former papers. I can only refer to my former letter to the Collector of Rajahmundry on this point, dated 17th April 1852, for further arguments. The grounds upon which I insist upon the necessity of making the channels navigable are therefore these :—

"*First*—The actual present traffic on those that have been opened is abundantly sufficient to prove the [illegible] for them.

"*Second*—There is now a large [illegible] increasing foreign trade, the materials of which must be carried from the [illegible] to the coast.

"*Third*—Among a population close on a million of people there must be a large interchange of goods, if there are communications.

"*Fourth*—The delta is wholly without roads.

"*Fifth*—It is much cheaper to make the irrigation channels navigable than to make roads, and they are incomparably better means of transit.

"*Sixth*—To supply the people with means of raising a five-fold amount of produce, and give them no means of conveying the surplus to the towns and ports where it may be converted into money, seems to me the most palpable mistake.

"*Seventh*—If only 100,000 tons are moved by the channels annually (the exports alone are from 40 to 50,000 tons already) and they are only conveyed on an average 30 miles, the cost of that traffic by land would be 4 lacs a year; whereas by water it will not exceed 40,000, so that it would be equivalent to relieving the district from a charge of 3½ lacs a year, even if there were roads.

"*Eighth*—The cost of the navigation will be quite insignificant, perhaps on an average 200 rupees a mile, the interest of which, divided among a traffic of only 10,000 tons a year, would be only half pice per ton per mile; and for this

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* No. 47, dated 14th January 1853.

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cost of transit would be reduced ten pice, even as compared with common ids, which would cost three or four times what the navigation will.

"*Ninth.*—I must always insist upon the fundamental principle, that where ere is a considerable population, it is the communications that make the traffic; and if there is little or no traffic, the sole reason must be that there are no communications"

And so he went on with steady insistence, loyally backed up by the Officers who followed him on the Delta works, till at last opposition to his views on the subject was broken down, and there are now in the Gódávari system alone nearly 500 miles of Canals which, besides carrying water for irrigation, are excellent lines of communication; nor is this all; from the Gódávari system navigation can at three places pass into the Kistna system with its 300 miles of navigable canals, and from it again into the 'Buckingham Canal,' which runs along the coast for 196 miles from the end of the Kistna system to Madras, and for 65 miles further south. From Cocanada to the south end of the '*Buckingham Canal*,' the length of Canal Navigation is 450 miles.

There cannot be the slightest doubt that the provision for cheap carriage, not only in and about the district itself, but also to the neighbouring districts and to an excellent seaport, contributed largely to the rapidity with which the Gódávari irrigation developed, and the district sprang into prosperity. In this way the cost of the works specially required for Navigation has been repaid over and over again, quite irrespective of the direct returns from boat licenses, tolls and so on. This fact, however, has been obscured by the practice of attempting to show the financial results from *Navigation* separately from those due to *Irrigation*; the following are extracts from a 'Note' on the ubject by the then Chief Engineer for Irrigation, in 1890; ad said

". . . . No attempt should be made at separation of [illegible] and charges etween Irrigation and Navigation, or at all events there should be no consideration them separately; the *total* receipts under both heads should be compared with e *total* charges.

"2. When in the same canal or system of canals Irrigation and Navigation e combined, the works for the two purposes are so interwoven, as it were, that is impossible to arrive with any accuracy at the share of original cost due to ch; and it is still more impossible to separate the cost as regards 'Maintenance d Repairs.' It is, f example, impossible to tell with even approximate accuracy ow much of the necessary silt clearance, or bank-repairing, is due to Irrigation, ow much to Navigation.

"3. The attempt at separation as now carried out is not only useless but mischievous, for it has resulted in the misconception that the making of the Gódávari nd Kistna canals navigable has not paid, whilst the truth is that it has been to Government an excellent investment.

"4. It must be remembered that Government is in this matter on an entirely different footing from private owners of canals; the latter get only the *direct* returns, the absolute payments for use of the canals; whilst the former in addition to the direct returns receives indirect benefits and returns which cannot be tabulated, but which largely outnumber and exceed in importance, and even in money alue, those which *are* brought to book. The increased comfort and prosperity the people resulting from cheap communications cannot be shown in money lumns, nor is it possible to credit to Navigation the portion of the enhanced venue under excise, salt, stamps, and so on, really due to it.

"5. For example, after the construction of the combined Irrigation and avigation works in the Gódávari Delta the imports and exports of the District creased rapidly, they doubled in a little over ten years; in twenty years they had increased four-fold, and in thirty-five years upwards of ten-fold; so wit general revenue; the district which for many years had not paid the cost of administration soon rose to the second place amongst the great revenue yiel districts of the Presidency, whilst the population of the delta has about treb itself. It is certain that these splendid results compared with which the direc navigation collections from licenses and tolls are insignificant, would not hav been achieved so rapidly, and it is probable they would never have been reache at all, had it not been that the delta is intersected by navigable canals whic make it easy to export the produce due to irrigation, and which bring salt an the various commodities required by a well-to-do people almost to their ver doors."

But, though the combination of the two duties of Irrigation and Navigation has been most successful in the canals of the Delta, it is not entirely without drawbacks even there, especially on the High-level canals, and it is but right that those drawbacks should receive some notice. With this object the following extract is given from a 'Memorandum' written* in 1888 i support of a proposal for a railway between the Kistna and Gódávari rivers, proposal which has since developed into the 'East Coast Railway':—

"CANALS for the combined purposes of irrigation and navigation, with specia reference to such canals in the Gódávari district, and the necessity fo providing other means of traffic between the Kistna and the Gódávari.

"It may be accepted as an axiom in canal engineering that the requirement of irrigation and navigation are conflicting, *e.g.*, for *irrigation* large quantities water, and consequently of silt, have to be taken into a canal, and therefore th slope of the surface must be considerable; for *navigation*, the less water tak into the canal, the better, and its surface should have no slope; for *irrigati* there are times when the canal should be kept low, so that large quantities surplus water may not have to be passed into the drainages when they a already filled by rain-water; for *navigation* the canal should always be kept up its full level; for *irrigation*, even when the river or other source of supply is lo it is often necessary to go on letting as much water as possible out of the ca to supply crops, thereby reducing the level and the depth in the canal, especi at its end; for *navigation* at such times the water should be kept in the canal, maintain as nearly as possible its full depth.

"2. The canals of the Gódávari delta are primarily for *irrigation;* they h been made also navigable to supplement their usefulness, and never has th been a more successful combination. Its very success, however, now threate especially on the through lines, to cause the secondary object of the canals over-top and seriously interfere with the primary one.

"3. The clashing of the irrigation and navigation requirements mentioned para. 1 is well exemplified on the Ellore canal, which is the through line of con munication between the Kistna and the Gódávari river. On that canal considerable silting, inevitable when large quantities of water have to be passed throug a canal from a silt-bearing river, frequently impedes traffic, whilst the necessit for keeping sufficient water for heavily-laden boats leads at times to more wate being taken into the canals and surplussed out, and at other times to less wate being given out of the canal to its distributaries, than suits the irrigation; and is a fact that much tempting and perfectly possible extension of irrigation fro near the end of the canal has to be foregone, because it would still further add the already great difficulty at times of keeping the navigation going.

"4. On this (Ellore) canal especially, the staff of this department has attempt to serve the two antagonistic interests with the inevitable result t her is satisfied. The one that has for its mouth-piece the powerful commer- community of Cocanada can best make its voice heard in high quarters, but trict officers know that the other has much to say from an entirely different int of view.

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* By Mr. G. T. Walch, then Superintending Engineer, 1st Circle.

"5. The truth is that up to a certain point of development of traffic the con- cting interests can be fairly well reconciled but not beyond, *and that point has ready been reached on the Ellore canal;* what then will be the case when to the isting and increasing general traffic along that canal is added the coal traffic Cocanada? . . . . .

"As an addendum to my memorandum, I have the honour to say that in the ficial year 1887-88 there passed through the Dowlaishweram head lock 20,065 ats and 1,736 rafts, and through the Vizeshweram lock 24,254 boats and 2,943 fts."

The extent to which the Canal traffic has developed may be judged from e following 'Traffic Statement' for 1893-94; and it is interesting to te that this gives a result some *twenty* times as great as Sir Arthur Cotton ticipated in 1852, when he wrote, "I should not be surprised if, after a few ars, the district be well managed, and the Canals kept in good order, the ffic were to average *50 tons a day* :—"

TRAFFIC STATEMENT, GÓDÁVARI DELTA CANALS, 1893–94.

Sources of Navigation revenue.	Collections during 1893–94.	Nature of cargo.	Up traffic.	Down traffic.	Total tonnage both ways.	Value of goods.
1	2	3	4	5	6	7
	RS.		TONS.	TONS.		RS.
		BOAT TRAFFIC.				
		1. Cotton, raw and manufactured	5,751	2,459	8,210	32,59,889
		2. Woollen, raw and manufactured ...	8	5	13	32,125
		3. Dyes and tans ...	370	103	473	1,41,900
		4. Paddy and rice ...	45,515	28,569	74,084	24,57,152
		5. Other food-grains ...	2,009	8,006	10,015	4,99,921
		6. Hides and skins ...	207	272	479	3,84,667
		7. Liquors	522	912	1,434	5,72,813
		8. Metals	4,086	1,155	5,241	8,08,272
		9. Oils	1,629	542	2,171	3,26,805
		10. Oil-seeds	21,648	22,626	44,274	22,14,491
		11. Provisions	4,108	5,997	10,105	10,10,820
LICENSES AND TOLLAGE.		12. Salt	5,366	1,603	6,969	5,57,918
		13. Spices	203	118	321	3,06,210
		14. Sugar	3,536	14,247	17,783	11,43,119
		15. Tobacco	2,121	2,618	4,739	14,20,029
		16. Building materials ...	10,527	45,585	56,112	1,04,817
Government boats and steamers ...	5,382	17. Miscellaneous goods ...	8,118	5,967	14,085	9,99,081
		18. Timber	597	12,044	12,[illegible]41	10,11,533
		19. Firewood	4,347	2,815	7,162	43,001
Private passenger and cargo boats	76,886	20. Bamboos	337	8,682	9,019	1,80,469
Rafts	13,491	21. Coal and coke ...	3,136	1,850	4,986	59,842
Miscellaneous ...	5,617	22. Jute	...	..	...	...
Ground-rents ...	284	23. Treasure	27	1	28	48,88,3[illegible]
		Total, Boat Traffic 1893–94	124,168	166,176	290,344	2,24,23,204
		RAFT TRAFFIC.				
		24. Timber in logs ...	120	24,131	24,251	18,19,307
		25. Squared timber ...	364	1,760	2,124	1,69,920
		26. Sleepers, broad gauge.	143	92	235	37,600
		27. Do. metre do.	...	...	...	...
		28. Scantlings ...	44	1,012	1,061	63,660
		29. Poles	14	18,567	18,576	7,43,040
		30. Firewood	6	56,296	6	36
		31. Bamboos	832	...	57,128	11,42,701
		Total, Raft Traffic ...	1,523	101,858	103,381	39,76,264
Total ...	1,01,660	Grand Total, Boat and Raft Traffic, 1893–94.	125,691	268,034	393,725	2,63,99,468

NOTE.—The 'tonnage' and 'value of goods' are merely approximations, as the quantities and descriptions of goods are in almost all cases arrived at solely from information given by the boatmen who rarely have any 'manifests'.

The 'ton mileage' was 22,778,645. The number of passengers carried was 287,548.

The lockages of boats through the Head Locks of the three sections of the elta were in 1894–95 as follow :—

Boats.	Up Number.	Down Number.	Total Number.
Dowlaishweram Lock (E.D.) ..	10,908	11,167	22,075
Bobberlanka Lock (C.D.) ..	3,951	3,954	7,905
Vizéswaram Lock (W.D.) ..	12,482	12,214	24,696
Grand Total, Boats ..	27,341	27,335	54,676

The *numbers* of *Rafts* for the same year were not recorded.

The *direct* returns from Navigation, which, as said above, though by no eans the most important, are the only ones that can be tabulated, amounted 1893–94, as shown in the above Traffic statement, to Rs. 1,01,691.

For many years after the opening of the Navigation, no tolls appear have been enforced. In 1859 the then Governor Sir Charles Trevelyan rote thus: "The Godavery canals are all toll-free, as it has been wisely rmined that it is better to take the Government dues in a consolidated on the crops than to harass and mulct the people by exactions which ot be confined to those demanded on behalf of the public."

However in 1863 a license fee of one rupee per ton per annum was charged, some years subsequently this was raised to—

Cargo Boats.—License Rs. 2 per ton measurement of 50 cubic feet.
Passenger Boats.—License Rs. 4 per ton first class ; Rs. 3, second class.
Rafts, Timber.—Toll As. 4 per 100 square feet.
Rafts, Bamboos.—Toll As. 2 per 100 square feet.

These rates, which were slightly varied from time to time, referred only to Gódávari system of canals ; there were separate and different charges for Kistna system and for the Buckingham canal.

In 1882 the question of the Navigation charges and rules for all the three stems was gone into by a Committee whose proposals are to be found with G. No. 562 W., dated 20th February 1883. The rates proposed will seen in column 3 of the following statement, and in column 4 will be d the very extensive modifications proposed by the Chief Engineer for gation (Colonel J. O. Hasted, R.E.) and sanctioned by Government :—

———	Present (1882) rates per ton of 50 cubic feet.	Rates proposed by committee of October 1882.	Rates proposed by Chief Engineer for Irrigation and sanctioned by Government.	Remarks.
ANNUAL LICENSES.	ANNUAL LICENSES.	PER TON OF 50* CUBIC FEET PER ANNUM.	PER TON OF 50 * CUBIC FEET PER ANNUM.	* 15 per cent. deducted from gross measurement for net tonnage.
Cargo Boats.	Rs.	Rs.		
Gódávari	2⅓	2 Rs. 5 for through license.	Rs. 2½ to clear all the canals.	† The Buckingham Canal was divided into six sections.
Kistna...	1⅔	1½		
Buckingham Canal...	2 per section, † 10 for whole canal.	3		
Passenger Boats, 1st Class.				
Gódávari	4⅔	4 Rs. 10 ,,	Rs. 5 ,,	
Kistna	4⅔	4		
Buckingham Canal ...	2 per section, 4 for whole canal.	4		
Passenger Boats, 2nd Class.				
Gódávari	3⅓	3 Rs. 7 ,,	Rs. 3 ,,	
Kistna	3⅓	3		
Buckingham Canal ...	2 per section, 4 for whole canal.	3		
Steamers.				
Gódávari	5	4† Rs. 10 ,,	Rs. 5 ,, †	One-third deducted from gross measurement for net tonnage.
Kistna	5	3		
Buckingham Canal ...	As cargo on passenger boats.	6		
TOLLS.	TOLLS.			
Rafts, Timber.				
Gódávari	4 annas per 100 square feet *each canal.*	8 annas per 100 square feet for each system for one month.	8 annas per 100 square feet for *each system* for one month.	
Kistna	Do.	Do. ...		
Buckingham Canal ...	1 anna per square yard.	Do. ...		
Rafts, Bamboo.				
Gódávari	2 annas per 100 square feet.	4 annas per 100 square feet for each system for one month.	4 annas per 100 square feet for *each system* for one month.	
Kistna	Do. ...	Do. ...		
Buckingham Canal ..	1 anna per square yard.	Do. ...		
Vessels.				
Gódávari	4 annas per ton *each canal.*	8 annas per ton per system for six weeks.	8 annas per ton for six weeks over all canals in any direction.	
Kistna	Do. ...	6 do. ...		
Buckingham Canal ..	4 annas per ton *each section of canal.*	12 do. ...		
Steamers.				
Gódávari	Same as vessels.	1 rupee per ton per system for six weeks.	1 rupee per ton for six weeks over all canals in any direction.	
Kistna	...	12 annas do. ...		
Buckingham Canal ...	...	1½ rupees do. ...		

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The main features of the new arrangement were the reduction in the number of toll stations, which had been found to harass traffic, and the discontinuance of separate licenses for each system, in favour of a 'compound rate' covering all the systems. As bearing on these subjects, the following extracts from the Memorandum of the Chief Engineer for Irrigation are given :—

"8. . . . The Committee consider that tolls cannot be entirely abolished, but that to allow of the occasional use of the canals without taking out a license, toll stations must be maintained at the head locks of each section of the deltas, all tidal locks, at Ellore near the junction of the Gódáveri and Kistna Canals, and four places on the Buckingham Canal, for the public convenience, thus reducing the number of toll stations from 47 to 20. To these proposals I agree on the understanding that the toll stations are maintained for the public convenience only, that no obstructions such as now exist in the shape of a chain drawn across the canal shall be allowed, and that the toll-taker has no authority to stop any boat or call for the production of its license unless there is some apparent infringement of the rules. A subordinate in the position of a Lock Superintendent or toll-keeper should never be allowed the powers of an Inspecting Officer. The toll-keepers should be restricted to issuing toll tickets when called upon to do so. It is better to risk some laws than to harass the traffic. . . . .

"10. The Committee give the rates at which they propose to fix license fees and tolls, and here they follow the system at present in force to some extent. They propose a separate license fee for each system, and a compound rate for all these systems, but they do not propose to retain the present plan of charging a separate fee for each section of the Buckingham Canal. Passenger boats of both classes are dealt with in the same way as cargo boats, also steamers. I am prepared here to go a great deal further than the Committee. What I desire to see is one demand to clear all the canals. I would remove all obstacles in the way of Navigation that I possibly could, believing that the interests of Government will be best served by improving the communications, stimulating consumption, and consequently extending production.

"11. . . . I do not look for an immediate return, but I do expect that the opening of the canal to traffic in this way will eventually prove remunerative to Government, and I allow that it will be practicable to raise these rates at some future time :—"

The advisability of returning to the method of separate licenses for each system of canals and of raising the rates for licenses and tolls, in order to secure a larger direct revenue from Navigation, is now under consideration.

The annual Maintenance Charges against Navigation are to some extent purely arbitrary, and to show the method on which they are assessed, the following statement for 1893–94 is appended :—

Description.	Total charges for 1893-94.	Debitable to Navigation.		Debitable to Irrigation.	
		Rate.	Amount.	Rate.	Amount.
	RS.		RS.		RS.
1. Navigation establishment	23,001	Whole ...	23,001	...	...
2. Locks and weirs repairs	22,690	Do. ...	22,690	...	...
3. Navigation buildings	833	Do. ...	833	...	...
4. Towpath maintenance	2,150	Do. ...	2,150	...	...
5. Dredging	4,178	Do. ...	4,178	...	...
6. Share of canal maintenance	(*a*) 55,954	One-fourth .	13,988	Three-fourths.	41,966
7. Repairs of staff boats	1,808	Whole ...	1,808	...	...
8. Charges for painting numbers on boats	244	Do. ..	244	...	...
9. Miscellaneous (including charges not appertaining to the first eight items)...	8,437	One-fourth.	2,109	Three-fourths.	6,328
Total ...	1,19,295	...	71,001	...	48,492

(*a*) This amount represents expenditure on the following items :—

(1) Repairs to canal banks (one-fourth of this is chargeable to Navigation).
(2) Silt clearances (do. do. do.).
(3) Mile and avenue coolies (do. do. do.).

There are complete 'Rules' dealing with 'Licenses,' 'Tolls,' 'Wharfage fees,' and general 'Regulations' for navigation, but it seems unnecessary to give them here, as they are somewhat lengthy, and moreover are not unlikely to be considerably modified before long.

Towage of Boats.

Manual labour as the motive power for boats is extensively used, but the waterway of most of the canals is so broad that sailing is largely resorted to. The passenger, or 'Rahadari,' boats have two large lateen sails, the peaks of which rise high above the banks, whilst barges or 'Dhonies' are generally square-rigged and often carry 'Main,' 'Top,' and 'Top-gallant' sails, and sometimes even 'Royals.'

Of course the introduction of steam power for the transportation of freight along the canals has often been considered, and it has to some extent been tried, but without success. It cannot compete with manual labour, unless that becomes far less plentiful and cheap than it now is, and unless the canals along the chief lines of communication be maintained *along their whole lengths and at all points* to a depth greater than is now the case. As bearing on this interesting subject, the following information is given about it, in connection with one of the most important artificial inland waterways of the world, the Erie Canal in the New York State, running from Lake Erie at Buffalo, to the Hudson River at Albany, a distance of 363 miles. Up to nineteen* years ago, all attempts to introduce financially successful steam navigation on that Canal had failed, and this though it had to compete only with the haulage by animal power there used, which is many times more expensive than that by manual labour in the Gódávari District. In the last few years, however, continuous attention to the subject has resulted in such improvements to the steam-tugs and the general towing arrangements connected with them, that their use on the Canal is gradually extending. To secure this result, however, it has been found necessary to lengthen the Locks considerably and to maintain the depth of water in the Canal at not less than 7 feet; a low rate of speed has also had to be adopted, under 3 miles† an hour on the average.

That steam, or perhaps electricity, will eventually supersede the towing coolie on the Gódávari Canals is most probable, but this will not be for many a long day yet.

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* *See* page 81 of "Navigable Rivers and Canals of the United States and Canada."—WALCH

† Report of State Engineer, State of New York, for 1891.

CHAPTER XII.

RESULTS OF THE GÓDÁVARI DELTA WORKS.

THE financial and other results of the Gódávari Delta System of Irrigation and Navigation have already received notice in various parts of this History, but it will be well to group the information regarding the more important of them in one Chapter.

I.—DIRECT MONEY RETURNS.

	RS.	RS.
Total CAPITAL Expenditure including 'Indirect charges' since 1847–48 to end of 1893–94, *see* Appendix No. I	..	1,28,08,662
TOTAL RECEIPTS from the Works to end of 1893–94	6,20,15,013	
But of this, assumed as due to irrigation existing before the works of the system were commenced	39,56,462	
		5,80,58,551
TOTAL EXPENDITURE and Charges on REVENUE ACCOUNT (*Minor Extensions and Improvements, Maintenance, Interest Charges, see* Statement at end of Chapter VII) to end of 1893–94	..	2,95,69,867
CLEAR SURPLUS of Receipts over 'Revenue' Expenditure and Charges to end of 1893–94.	..	2,84,88,684

or considerably more than double the whole Capital expended; and this it must be remembered is after having provided interest on the money spent; for such interest has been, and is still being, charged at 4 per cent. year by year against the Works, though it might have been extinguished long ago by means of a sinking fund raised from the surplus profits.

The net *Annual Revenue* of the System *after* paying interest at 4 per cent. gives upwards of 10 per cent. on the Capital outlay, or upwards of 14 per cent. were interest charges not made; this is shown in the following statement for 1893–94:—

Capital Outlay, Direct and Indirect, to end of 1893–94.	Revenue Receipts in 1893–94 due to the System.	Working Expenses in 1893–94.	Net Revenue in 1893–94 due to the System.	Percentage of Net Revenue on Capital Outlay in 1893–94.	Interest on Capital Outlay.	Surplus Revenue after deducting Interest.	Percentage of Surplus Revenue on Capital Outlay after charging Interest.
RS. 1,28,08,662	RS. 24,14,627 *	RS. 6,15,880 †	RS. 17,98,747	14·04	RS. 4,36,492	RS. 13,62,255	10·64

* Exclusive of Rs. 1,24,000 assumed as due to old Irrigation.

† Exclusive of Rs. 8,500 assumed as chargeable to old Irrigation.

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II.—GROWTH OF REVENUE OF THE DISTRICT.

Table 21 of the '*Gódávari District Manual*' gives year by year "The Actual Collections in the Gódávari District under all items of Revenue, from 1820 to 1875-76." Taking intervals of ten years back from the completion of the Anicut, the entries in that Statement are —

	RS.
In 1823-24	21,84,747
In 1833-34	26,91,719
In 1843-44	17,25,841

and the following statement gives similar information, but with details as to the various sources of Revenue, since the completion of the Anicut, in 1852:—

Sources of Revenue.	In 1853-54.	In 1863-64.	In 1873-74.	In 1883-84.	In 1894-95.
	RS.	RS.	RS.	RS.	RS.
Land Revenue and Water-tax	20,38,135	35,48,159	41,50,386	44,03,232	55,18,266
Income tax	*Nil*	53,225	* 948	† 25,337	1,34,451
Stamps	16,219	1,13,611	2,42,845	3,34,363	5,17,198
Abkári	92,529	1,85,712	2,43,497	2,92,930	12,70,280
Opium	*Nil*	*Nil*	*Nil*	2,91,733	2,90,351
Sea Customs	33,624	26,800	78,813	6,757	86,588
Salt	2,25,164	3,14,788	5,45,429	8,17,336	10,04,188
Moturpha ‡	54,792	...	...	...	...
Totals ...	24,60,463	42,42,295	52,61,918	61,71,688	88,21,322

* In 1873-74 income tax temporarily abolished.

† 'License' tax.

‡ Taxes on manufacturing and trading community.

From this it will be seen that the total Revenue raised in the District has in forty-one years increased from 24 lakhs to 88 lakhs; and besides this there are now large sums collected as 'Local' and 'Municipal' taxes which did not exist in the old days. The whole of the increase is not, of course, due to the Delta Works, but most certainly far more is due to them than merely the Rs. 24,14,627 § with which they are credited. The whole of that sum is included in the above statement under 'Land Revenue and Water-tax,' the increase under which has, it will be seen, been upwards of 35 lakhs in the forty-one years; but all the other sources of revenue are also largely affected by the increase in population and general prosperity which has resulted from the construction of the Anicut and of the other Irrigation and Navigation Works which have followed it.

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§ In 1893-94 (*see* Statement on page 153).

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III.—IMPORTS AND EXPORTS.

The year before the commencement of the Anicut, the values of the Imports and Exports of the District were Rs. 3,88,749 and Rs. 9,07,774 respectively. Eight years later, in *1853–54*, when the Anicut had been completed and the water from it partially distributed, the Exports had more than doubled, though there was a temporary falling off in the Imports. The subsequent growth of the Import and Export trade is shown at intervals of ten years in the following table; the figures there given are exclusive of 'bullion and specie,' the returns for which are largely affected merely by the movement of Government treasure:—

Year.	Imports.	Exports.	Totals.
	RS.	RS.	RS.
1863–64	9,34,026	47,78,780	57,12,806
1873–74	16,20,870	67,19,136	83,40,006
1883–84	24,85,068	1,40,99,520	1,65,84,588
1893–94	37,06,955	1,54,59,084	1,91,66,039

So that the Imports are now nearly ten times, and the Exports more than twenty times, as great in value, as they were before the Anicut was built.

IV.—POPULATION.

In Sir Henry Montgomery's Report of 18th March 1844, quoted from in Chapter II, he gives a table of population of the District showing it to have decreased from 738,308 in 1821–22 to 561,041 in 1842–43. Those figures were probably but rough approximations, as no count of the people was taken with accuracy till 1851–52. The Census of that year gave the population as 1,012,236 and the Census of five years later as 1,081,703. As however the boundaries of the district were considerably altered in 1859, no comparison between its population before and after that date is of value. The Census of 1861 gave a total of 1,366,831, whilst the last one of 1891 gave 2,011,982 (exclusive of the Bhadráchalam-Rékapalle Taluk, and Kottapalle Taluk not included in the count of 1861), an increase of slightly over 47 per cent. in thirty years.

The count was made according to Taluks for the first time in the Census of 1866–67, which, with the following Censuses of 1871, 1881 and 1891, will be found in Appendix No. II. To it have been added columns of areas of the Taluks and the density of population in them, from which it will be seen that the Taluks mostly under the influence of the system of Irrigation from the Anicut, over an area of upwards of 2,000 square miles, support a population of from a little over 500, to a little less than 600, to the square mile. This is considerably greater than the average of Belgium, the most densely populated country in Europe.

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V.—Cultivation.

The area of irrigated land in the Delta has increased from less than 150,000 acres of precarious cultivation, to (in 1893-94) 640,744 acres of 'first' crop, and 80,966 acres of 'second' crop, which are grown with almost absolute certainty, whilst large areas of 'dry' crops, garden cultivation, cocoanut plantations, and so on, that do not ostensibly 'take' water for their irrigation, and therefore do not pay water-tax, are greatly benefited by the presence of the Canals and Channels, and by the improved means of drainage which have been provided.

VI.—Communications.

Less than fifty years ago the Deltaic portions of the District were without any internal means of communication except rough and devious footpaths along which such traffic as there was, had to be carried on, slowly and painfully, by coolies or pack-cattle. The year after the Anicut was completed Sir Arthur Cotton wrote: *

"Salt is now carried over a great part of the country on men's shoulders; and the cost is so greatly enhanced in each ten miles, that the consumption is a mere trifle to what it ought to be in a great portion of the Delta.

"But no result of the Navigation within the district will be more striking than its effect on the amount of human labour that it will render available for better purposes than those to which it is now applied. At present the cavady cooly carrying 100 lbs. is the most general means of transporting grain in the Delta. By the channels (even with the clumsy river boats now brought into use) four men navigate a dhony laden with 12 Rajamundry garce of rice. To carry one of these garce takes 45 men; so that four men can thus be made to do the work of 540, or each cooly that of 135."

Now, the Delta is intersected by nearly 500 miles of excellent navigable canals affording the cheapest of all means of inland carriage, and there is also another 500 miles or so, of well-made roads for wheeled traffic, constructed chiefly from Local Funds, which the great prosperity of the district has rendered it possible to collect within itself.

VII.—General.

"The annals of this District, since it came under the English Government, form a varied record of temporary depression and subsequent improvement. At the commencement of our rule, it constituted a portion of a neglected province; and, at one time, it was, from various causes, brought into a state of extreme impoverishment and distress. It was desolated by famine and misgoverned by the numerous land-owners and their advisers. Since the introduction, however, of the admirable system of irrigation, which, in a previous chapter, I have endeavoured to describe, it has brightened and revived. Famine is unknown. The people are prosperous and contented. It is the garden of the great Northern Province. Its revenue, instead of being reduced, as it once was, to the verge of bankruptcy, is more elastic than it has ever been; its population has more than doubled; the material prosperity of its inhabitants is proved by their being better fed, better clothed, and better educated than formerly; its commerce has flourished, and its trade has

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* Letter to Secretary to Board of Revenue, dated 23rd February 1853.

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veloped to a marvellous degree; and it may confidently be asserted that it in as peaceful, happy, and prosperous condition as any part of Her Imperial ajesty's dominions."

These words form the concluding paragraph of the *Gódávari District* *anual* written some twenty years ago by Mr. H. Morris, whose official connection with the District gave him special knowledge on the subject. They quoted as being no less true now than when they were penned. Still is ine unknown in the District, for famine in India is born of prolonged ught, from the effects of which the Delta is secured by the abundant water ed over it from the Gódávari. And not only is the District thus secured nst scarcity in itself, but it is enabled to send largely of its superfluity of grains to less favoured districts. Still does the population increase and aterial prosperity improve. Still does commerce develop and the revenue and.

hat these results are largely due to the great Engineering works of ich this History treats, is not open to question, and it is not too much to that whether regarded in their Engineering, Financial, or Social aspects, y rank high amongst the many splendid Public works which testify to the eficent vigour of England's rule in India.

APPENDIX No. I.

Statement showing the Expenditure incurred on CAPITAL Account of the Gódávari Delta System.

Years.	Direct Charges.						Indirect Charges.			Total Direct and Indirect Charges.	Remarks.
	Works.	Establishment.	Tools and Plant.	Loss by Exchange.	*Less* receipts on Capital Account.	*Net Total.*	Capitalized abatement of Land Revenue.	Leave and Pension Allowances.	Total.		
1	2	3	4	5	6	7	8	9	10	11	12
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	
1847-48 ...	1,92,796	40,078	20,806	...	...	2,53,680	84,463	8,516	92,979	3,46,659	Anicut begun.
1848-49 ...	1,92,796	40,078	20,806	...	...	2,53,680	...	8,516	8,516	2,62,196	
1849-50 ...	1,92,796	40,078	20,806	...	...	2,53,680	24,176	8,516	32,692	2,86,372	
1850-51 ...	1,92,795	40,078	20,806	...	...	2,53,679	17,667	8,516	26,183	2,79,862	
1851-52 ...	1,92,796	40,078	20,806	...	...	2,53,680	66,272	8,517	74,789	3,28,469	Anicut and Head Works finished. Gunnaram Aqueduct begun, *end* of year.
1852-53 ...	3,72,819	77,571	20,805	...	...	4,71,195	47,633	16,484	64,117	5,35,312	Gunnaram Aqueduct finished.
1853-54 ...	2,44,702	50,869	28,048	...	...	3,23,619	90,349	10,810	1,01,159	4,24,778	
1854-55 ...	4,16,210	86,521	43,664	...	...	5,46,395	2,96,795	18,386	3,15,181	8,61,576	Ellore Canal commenced.
1855-56 ...	4,56,336	94,863	23,316	...	...	5,74,515	1,14,829	20,158	1,34,987	7,09,502	Narsapúr Canal begun.
1856-57 ...	3,40,830	70,851	23,747	...	...	4,35,428	97,663	15,056	1,12,719	5,48,147	Canal from Samalkot to Cocanada and Extension of Ellore Canal, in hand.

APPENDIX No. I—*cont.*

Statement showing the Expenditure incurred on CAPITAL Account of the Gódávari Delta System—cont.

Years.	Direct Charges.						Indirect Charges.			Total Direct and Indirect Charges.	Remarks.
	Works.	Establishment.	Tools and Plant.	Loss by Exchange.	*Less* receipts on Capital Account.	*Net* Total.	Capitalized abatement of Land Revenue.	Leave and Pension Allowances.	Total.		
1	2	3	4	5	6	7	8	9	10	11	12
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	
1857-58 ...	1,60,720	33,410	20,806	...	...	2,14,936	36,390	7,100	43,490	2,58,426	Expenditure restricted on account of the Mutiny.
1858-59 ...	51,222	10,648	20,806	...	...	82,676	1,08,548	2,263	1,10,811	1,93,487	
1859-60 ...	1,11,143	23,104	20,806	...	...	1,55,053	50,670	4,910	55,580	2,10,633	
1860-61 ...	80,480	16,730	20,806	...	...	1,18,016	51,398	3,555	54,953	1,72,969	
1861-62 ...	1,11,265	23,130	20,805	...	...	1,55,200	24,149	4,915	29,064	1,84,264	
1862-63 ...	2,16,686	45,045	20,806	...	...	2,82,537	19,089	9,572	28,661	3,11,198	
1863-64 ...	2,98,728	62,099	20,806	...	...	3,81,633	12,532	13,196	25,728	4,07,361	Enlarging the Samalkot Canal and the Mundapetta Canal, in hand.
1864-65 ...	1,35,336	28,134	20,806	...	...	1,84,276	35,725	5,979	41,704	2,25,980	
1865-66 ...	34,305	7,131	20,806	...	...	62,242	23,260	1,515	24,775	87,017	
1866-67 ...	92,520	19,233	20,805	...	...	1,32,558	3,237	4,087	7,324	1,39,882	
1867-68 ...	1,27,863	26,580	3,197	...	...	1,57,640	5,373	5,648	11,021	1,68,661	
1868-69 ...	1,94,646	40,463	4,866	...	...	2,39,975	10,499	8,598	19,097	2,59,072	
1869-70 ...	1,18,844	24,705	2,971	...	...	1,46,520	12,718	5,250	17,968	1,64,488	
1870-71 ...	85,819	17,840	12,798	...	...	1,16,457	8,196	3,791	11,987	1,28,444	
1871-72 ...	1,59,776	33,214	5,968	...	...	1,98,958	17,781	7,058	24,839	2,23,797	
1872-73 ...	2,44,674	50,809	1,66,744	...	...	4,62,227	16,207	10,797	27,004	4,89,231	"*Completion Estimates,*" Eastern and Western Deltas, sanctioned.

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APPENDIX No. I—*cont.*

Statement showing the Expenditure incurred on CAPITAL Account of the Gódávari Delta System—cont.

Years.	Direct charges.						Indirect Charges.			Total Direct and Indirect Charges.	Remarks.
	Works.	Establishment.	Tools and Plant.	Loss by Exchange.	*Less* receipts on Capital Account.	*Net* Total.	Capitalized abatement of Land Revenue.	Leave and Pension Allowances.	Total.		
1	2	3	4	5	6	7	8	9	10	11	12
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	
1873-74 ...	2,35,921	49,043	7,068	...	15	2,92,017	24,431	10,422	34,853	3,26,870	
1874-75 ...	3,13,768	65,210	31,674	...	2	4,10,650	16,816	13,857	30,673	4,41,323	
1875-76 ...	3,38,571	90,331	21,679	...	509	4,50,072	25,943	19,196	45,139	4,95,211	
1876-77 ...	1,52,900	75,905	14,766	...	...	2,43,571	38,898	16,130	55,028	2,98,599	
1877-78 ...	1,42,785	79,637	34,210	...	94	2,56,538	21,604	16,923	38,527	2,95,065	
1878-79 ...	88,567	96,915	9,287	...	...	1,94,769	8,924	20,594	29,518	2,24,287	Grants restricted on account of financial pressure.
1879-80 ...	82,987	97,094	13,867	...	...	1,93,948	488	20,632	21,120	2,15,068	
1880-81 ...	1,09,041	23,386	5,304	...	...	1,37,731	186	4,970	5,156	1,42,887	
1881-82 ...	73,308	17,091	8,765	...	...	99,164	14,413	3,632	18,050	1,17,214	
1882-83 ...	1,56,577	34,414	29,043	...	...	2,20,034	...	4,875	4,875	2,24,909	'*Completion Estimates*,' *Central Delta*, and *Revised* Estimates, Eastern and Western Deltas, sanctioned.
1883-84 ...	2,99,824	65,568	62,481	690	43	4,28,520	12,881	9,180	22,061	4,50,581	
1884-85 ..	2,94,506	66,009	12,740	630	5	3,73,880	[illegible],579	9,241	20,820	3,94,700	
1885-86 ...	2,44,224	54,674	6,258	3,658	209	3,08,605	16,341	7,654	23,995	3,32,600	
1886-87 ...	1,75,031	39,221	−64,388	534	...	1,51,394	6,497	5,491	11,988	1,63,382	
1887-88 ...	1,33,280	30,113	31,539	...	...	1,94,220	4,899	4,216	9,115	2,03,335	
1888-89 ...	68,549	15,435	12,207	...	22	95,186	9,587	2,161	11,748	1,06,934	
1889-90 ...	56,624	12,268	3,486	...	...	72,308	4,471	1,718	6,189	78,497	End of 1889-90. "Completion Estimate" closed.

APPENDIX No. I—*cont.*

Statement showing the Expenditure incurred on CAPITAL Account of the Gódávari Delta System—cont.

Years.	Direct Charges.						Indirect Charges.			Total Direct and Indirect Charges.	Remarks.
	Works.	Establishment.	Tools and Plant.	Loss by Exchange.	*Less* receipts on Capital Account.	*Net* Total.	Capitalized abatement of Land Revenue.	Leave and Pension Allowances.	Total.		
1	2	3	4	5	6	7	8	9	10	11	12
	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	RS.	
1890-91 ...	23,079	4,430	— 16,765	—534	21	9,759	2,409	620	3,029	12,788	Expenditure on, socalled, "Open Capital sanctions."
1891-92 ...	46,261	9,827	9,277	...	13	66,551	634	1,376	2,010	68,561	
1892-93 ...	1,248	145	...	...	...	1,647	2,018	20	2,038	3,685	
1893-94 ...	2,090	451	...	...	...	2,541	1,779	63	1,842	4,383	
Total ...	80,58,044	19,70,507	8,80,964	4,978	933	1,09,13,560	15,00,422	3,94,680	18,95,102	1,28,08,662	

Column 2, '*Works*'.—The expenditure from 1847-48 to 1866-67 is taken from statement No. 1 printed in P.M.G., No. 93, dated 13th January 1869. In this statement the expenditure from 1847 to 1851 is shown in the aggregate. In the absence of information as to the expenditure incurred in *each* year, the total expenditure was divided equally between those years.

Column 3, '*Establishment*'.—The charges from 1847-48 to 1866-67 were assumed at a sum which, when added to the charges shown against the years 1867-68 to 1880-81, would make the total agree with 25 per cent. on the total expenditure on works from the commencement to the end of 1880-81. The sum assumed was distributed between the several years from 1847-48 to 1866-67 in proportion to the outlay on works. The charges from 1867-68 to 1873-74 have been calculated by distributing the total cost of establishment in rateable proportion to the outlay on works under each head.

The charges from 1874-75 to 1881-82 were calculated at 25 per cent. on grant for, or expenditure on, works, whichever was greater, *plus* the proportionate share of the cost of the Chief Engineer for Irrigation and his establishment and the cost of special Survey Establishment.

The charges for 1875-76 to 1879-80 bear a very high proportion to the expenditure on works, as the charges were calculated on the *budget grants* which were subsequently reduced to a large extent.

The charges for 1882-83 to 1893-94 were calculated at 23 per cent. on expenditure on works exclusive of land compensation.

Column 4, *Tools and Plant*.—The charges for each year from 1847-48 to the end of 1866-67 were made up of one-twentieth of the total cost of machinery and floating plant supplied to the Delta, but not previously charged to it, *plus* the expenditure incurred on Boats and Machinery in each year.

In the absence of information as to the value of machinery and floating plant supplied each year, the total cost was distributed equally between the several years.

The charges for 1878-79, 1879-80, 1880-81 and 1881-82 comprise not only the actual charges, but also 2¼ per cent. on the grant, or outlay on works, whichever was greater, on account of general tools and plant.

The charges for 1882-83 comprise actual charges and 1½ per cent. for general tools and plant. For the remaining years the charges represent only actual expenditure.

Column 8, '*Capitalized abatement of Land Revenue*'.—The charges in this column represent sums, which at 4 per cent. will yield a revenue equal to the abatement of land revenue.

Column 9, *Leave and Pension Allowances*.—These charges were calculated up to 1881-82 at 25 per cent. on the amount of salaries taken at 85 per cent. of the establishment charges, and from 1882-83 at 14 per cent. on the gross establishment charges.

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APPENDIX No. II.

POPULATION *of the* GÓDÁVARI DISTRICT—*Censuses* 1866-87 *to* 1891.

Taluks.	Census 1866-67.	Census 1871.	Census 1881.	Census 1891.	Area in square miles.	Population per square mile.	Remarks.
IRRIGATED BY ANICUT WATER, MORE OR LESS.							
Cocanada	86,507	91,860	101,075	120,907	397	516	All extensively irrigated by Anicut water, except Pithápuram, of which only a small portion is so irrigated.
Pithápuram	74,392	79,606	68,161	83,824			
Rámachandrapuram	184,110	203,583	220,780	261,194	507	515	
Amalápuram	189,233	206,885	227,157	256,081	437	585	
Tanuku	152,052	167,491	188,306	204,048	366	557	
Narsapur	161,537	177,876	200,153	230,325	450	512	
Bhímavaram	83,826	92,457	108,599	121,994	416	293	Large area of Tidal swamps in Bhímavaram.
Ellore	118,735	136,875	149,308	171,985	729	235	Only a small part of Ellore taluk commanded by Anicut water.
NOT IRRIGATED AT ALL BY ANICUT WATER.							
Rajahmundry	100,924	128,901	131,196	153,559	2,058	75	Including the portions known as 'Agency tracts.'
Peddápuram	101,539	111,489	122,052	146,607	506	290	
Yernagúdem	130,383	145,715	159,364	179,857	1,249	144	
Tuni	44,234	50,201	68,806	81,601	419	194	
Kottapalle	...	...	14,756	24,464	820	30	'Rampa country.
Bhadráchalam and Rékapalle	Transferred from the Central Provinces in 1874.		35,656	42,336	911	46	
Grand Totals ...	1,427,472	1,592,939	1,795,369	2,078,782	...	...	

MINISTRY OF CULTURE · GOVERNMENT OF INDIA

GSL

INDEX.

A

Acreage irrigated, 104, 137, 155.
Akid Canal, foot-note, 128.
Alignment of Irrigation Channels, 131.
Amalapúr Canal, 123.
Anicut.— Proposals, 7–25 ; Sanction by Court of Directors, 27 ; Site, 28 ; Length, 28 ; Design, 29–33 ; Additions to Talus, 31 ; Supply of stone required for upkeep, 32 ; Head-works connected with, 33 ; Work commenced, 34 ; Progress of work, 34–61 ; First Supplemental estimate, 38 ; Damage by floods, 39 ; Second Supplemental estimate, 41 ; Court of Directors' despatch about, No. 15 of 1848, 44 ; Committee reports on, 45 ; Court of Directors' despatch No. 6 of 1849, 45 ; Damage caused by fresh, May 1849, 46 ; Fresh of September 1849, 48 ; Injury to end of Dowlaishveram branch, 49 ; Groynes in connection with, 50 ; Extension of Dowlaishveram branch, 50 ; Mr. Forbes' letter giving progress to beginning of 1850, 51 ; Temporary dam to close Ralli branch, 51 ; Ralli Under-sluices injured, 52 ; Colonel A. Cotton's report, 12th December 1850, 52 ; Proposal to lengthen Vijeswaram branch, 53 ; Completion of Anicut and head-works, 55 ; Colonel A. Cotton's report on, 55 ; Complimentary order of Government, 61 ; Services of Veenam Veranah, 62 ; Alterations in, 63 ; Placing cast-iron posts on, 63 ; Raising in 1862–67, and proposed further raising, 63 ; Serious breach in 1857, 63–65 ; Length of, &c., 117 ; Highest flood over, 117.
Apparow Channels, 5.
Aqueducts, 134.
Aqueduct Gunnaram, 72–84.
Area irrigated, 104, 137, 155.
Area of Delta, 3, 4, 5, 137.
Attili Canal, 127.

B

Baird-Smith, Colonel, 73, 131.
Bank Canal, Eastern Delta, 120.
Bank Canal, Central Delta, 122.
Bank Canal, Western Delta, 126.
Bank Canals—Remarks on, 123.
Basin—drainage of Godavari, 1.
Bazin's Formula, 132.
Beckley's Drain, 130.
Bellempudi Surplus Weir, 134.
Bendamúrlanka, 4.
Bendamúrlanka Canal, 124.
Bhoopiah or Bhúppaiya Channel, 6.
Biccavole Drain, 121.
Billakarru Canal, 124.
Boats—License Fees and Tolls, 149, 150.
Boats—Tonnage of, 152.
Bobberlanka Head Sluices, 67, 69, 122.
Bobberlanka Lock, 71, 122.
Bobberlanka Under-sluices, 122.
Bodapad Drain, 130.
Bondada Drain, 130.
Bridges, 135.

C

Canals, discharges, 118, 128.
Canal falls (Weirs), 133, 134.
Canals—Area of irrigation under, 129.
Canals, lengths, 121, 124, 129.
Canals—Navigation combined with Irrigation, 145, 146.
Capital Expenditure, 115 ; and Appendix No. 1.
Cast-iron posts on Anicut, 2, 63, 117.
Catchment basin, Godavari, 1.
Censuses, Appendix No. 2.
Central Delta, 3, 4, 5, 122–125.
Central Delta Head Lock, New, 71.
Central Delta Head Sluices—Destruction and rebuilding, 67—69.
Channels–Irrigation, alignment, 131.
Channels–Irrigation, length, 142.
Chatterton, Mr., 139.
Chettipet Weir, 125.
Cloth Trade, 7.
Cocanada, 4.
Cocanada Canal, 119.
Cocanada Canal Tidal Lock, 119.
Colair Lake, 5.
'Completion,' Estimates, 94–103.
Concrete, 132.
Coringa Port, 3, 4.
Coringa Island, 2, 3.
Cost of Works, 114, 115 ; and Appendix No. 1.
Cotton, Major F. C., 62, 82.
Cotton, Sir Arthur—Sent to report on Godavari, 9 ; First Report, 9–15 ; Second Report, 15–24 ; Letters and Reports on Design and Execution, 28–40 ; Goes on leave in 1848, 40 ; Returns and Reports 1850, 52 ; Reports completion of Anicut, 55 ; Extracts from letter sending estimates, Gunnaram aqueduct, 72 ; Reports about aqueduct, 80 ; Letter to Government, 86–90 ; Report on Anicut and Works, 91, 92 ; Memorandum about making Canals navigable, 104.

Court of Directors' despatches, No. 19 of 1846, 26; No. 15 of 1848, 44; No. 6 of 1849, 45.
Crest of Anicut, 63.
Crops, 140.
Cultivation, 155.

D

Datum for Delta Levels, 117.
Delta, Central, 3, 4, 5, 122–125.
Delta, Eastern, 3, 118–122.
Delta, Western, 3, 5, 125–130.
Description of whole system, Chapter VIII, 117–130.
Despatches—Court of Directors, 26, 44, 45.
Despatches—Government of India, 112.
Despatches—Secretary of State, 113.
DeWinton, Mr. W. B., 69.
Discharge of Godavari, 1, 2.
Discharges—Canal and Channels—Formula for, 132.
Distributaries—Length of, 142.
Dorward Lieut. A. R. F., R. E., 130.
Drainages, 121, 125, 129.
Drainage—area of the Godavari, 1.
Drainage Works, Ellore Canal, 127.
Drake-Brockman, Colonel R. R. E., R.E., 69.
Drift brought done the Godavari, 2.
Duty of water, 139.
Duvva Weir, 130.

E

Earthwork, 131.
Eastern Delta, 3, 118–122.
Eastern Delta Head Lock, 69, 70.
Eastern Delta Sluices, 71.
Eddies, 49, 50, 68.
Ellore Canal, 127, 146.
Embankments between branches of the Anicut, 117.
Embankments River, Central Delta, 125.
Embankments River, Eastern Delta, 122.
Embankments River, Western Delta, 130.
Erie Canal—Steam on, 152.
Escapes (*see* also 'Weirs'), 127.
Estimates, 85, 93, 94–103.
Expenditure 'Capital,' 114, 115; and Appendix No. 1.
Expenditure 'Revenue', 116.
Exports, 154.
Extension of Irrigation, 137–139.

F

Falls (*see* Weirs).
Famine in Godavari District, 7.
Financial results, 106, 153.
Fischer, General J. F., R. E., 94.
Floods in Godavari, 2.
Floods over Anicut, 117.
Floors of Masonry Works, 133.
Forbes, Mr. H., 51, 61.
Formula for Discharge of Channels, 132.
Foundations, 33, 132.

G

Garden Crops, 140.
Gates, Lock, 133.
Gautami-Godavari, 2, 3.
Godavari Anicut (*see* 'Anicut').
Godavari Delta (*see* 'Delta').
Godavari District, 3.
Godavari River, 1, 2, 3.
Gontéru drain, 130.
Gopalpuram Concrete Lock, 133.
Gorinkala Drain, 4, 5, 125.
Gostanadi, 5, 6, 13.
Gostanadi and Vélpúr Canal, 126.
Groynes—Remarks about, 50.
Gunnaram Aqueduct, 72–84.
Gunnaram Canal, 123.

H

Haig, Lieut. (now General) F. T., R. E., 73, 75, 80.
Hasted, Col. J. O., R. E., 99, 122, 149, 151.
Head Lock, Central Delta, 71, 118.
Head Lock, Eastern Delta, 69, 70, 118.
Head Lock, Western Delta, 65, 67, 118.
Head Locks—Traffic through, 149.
Head Sluices, Bobberlanka (Central Delta), 33, 67; Dowlaishveram (Eastern Delta), 33, 71; Vijéswaram (Western Delta), 33, 67.
Head Sluices of Distributaries, 134.
Head-works (*see* also 'Anicut'), 118.

I

Imports, 154.
Indravati River, 1.
Injeram Canal, 120.
Inlets, 119, 127.
Interest Charges, 107, 116.
Irrigation, Chapter X, 136–142.
Irrigation Channels, 131, 142.
Irrigation Sluices, 134.
Irrigation and Navigation combined, 143–146.

K

Kakaraparru Canal, 126.
Kaza Drain, 129.
Kovúr-Manjair Junction Canal, 120.
Kowsika (Kausika) Drain, 4, 5, 125.

L

Lawe, Colonel A., 25.
Length of Canals, 121, 124, 129.
Length of Distributaries, 142.
License Fees for Boats, 148–151.
Locks, 133.
Locks—Number of, foot-note, 143.

M

Madapollam, 6.
Main Canal, Central Delta, 122.
Main Canal, Eastern Delta, 118.
Main Canal, Western Delta, 125.

GSL

Maintenance—Cost of, 106.
Maintenance—charges against Navigation, 151.
Masonry and Masonry Works, 132–135.
Materials used in Masonry Works, 132.
Mead, Colonel H. R., R.E., 84.
Mitford-Smith, Mr., 67.
Mogaltúr Drain, 129.
Montgomery, Sir Hy. Report, 7, 8.
Mullins, Colonel (now General) J., R. E., 94, 99, 107, 137.
Mundapet Canal, 120.

N

Naggaram Aqueduct (*see* Gunnaram Aqueduct).
Naggaram Island, 4, 72, 75.
Nakkala Drain, 6, 129.
Nandamúr Aqueduct, 127, 128.
Narsapúr, 6.
Narsapúr Canal, 126.
Navigation, Chapter XI, 143–152.

O

Ogee Falls, 134.
Orr, Captain C. A. (afterwards General) assumes charge of Anicut Works, 40 ; Various reports by, 41–52 ; Goes to Kistna works, 62.
Outlets—Ellore Canal, 127.
Over-fall vertical—Effect of, 31, 134.
Over-fall with Sloping Aprons, 31.

P

Paingange River, 1.
Pandi Kodu Drain, 130.
Paul, Mr. J. E., 70.
Pichikalanka, 28, 50.
Polaram Island, 4, 122.
Polaram Village, 1.
Population, 155, and Appendix No. 2.
Posts on Anicut, 63.
Pranbita River, 1.
Prendergast, Mr. T., 25.

R

Rafts, 148–150.
Rain-fall, 142.
Ramanah Naidu, 67.
Results, Chapter XII, 153–157.
Returns, 153.
Revenue of District, 154.
Rice Cultivation, 139.
Rules for Navigation, 152.
Rules for Water Rates, 140–142.
Rundall, General F. H., R. E., 64.
Rundall, Mr. J. W., 94.
Ryves Capt. J. G., R. E., 94, 137, 138.

S

Sabari or Severi River, 1.
Sage, Mr., 94.
Sailing on Canals, 152.
Samalkót Canal, 118.
Sangady, 135.
Scouring Sluices (*see* 'Under-sluices').
Sluices, Head (*see* 'Head-sluices').
Sluices, Irrigation, 134.
Somers-Eve, Mr., 70.
Steam Navigation on Canals, 152.
Surplus Weirs, 134.
Súrki, 132.

T

Teki Drain, 121.
Tolls on Canals, 148–151.
Topping, Mr., 7.
Towing on Canals, 152.
Traffic on Canals, 148.
Trimbak, 2.
Tuliabaga Drain, 4, 121.
Tuliabaga Aqueduct, 121.

U

Under-sluices, 33, 71.
Undi Canal, 128.
Unnamalanka Project, 130.
Upputéru, 5.

V

Vainateyam-Godavari, 2, 4.
Vasista-Godavari, 2, 4, 5.
Veenam Veranah, 62.
Venkiah and Weyeru Canal, 128.
Vizéswaram Head Locks, 65, 67.
Vizéswaram Head Suices, 67.
Vriddha-Gautami-Godavari, 2, 4.

W

Wainganga River, 1.
Walch, Mr. G. T., 67, 70, 146.
Wardha River, 1.
Water—Duty of, 139.
Water Cushions, 134.
Water-Distribution Statement, 104.
Water-rates, 140–142.
Weirs, 133, 134.
Wells, Foundation, 68.
Western Delta, 3, 5, 125–130.
Wéyeru, 5.
Wybrow, Mr. G. D., 67.

Y

Yanam, 3.
Yanamaduru Drain, 130.

H-63

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